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(54) Title: PATH INFORMATION BASED ON REFERENCE AND SENSING SIGNALS

(57) Abstract: Aspects relate to path information for wireless communication. In some examples, a user equipment (UE) transmits path information to a network entity. The path information may be based on signals received at the UE and objects sensed at the UE. In some examples, a network entity configures a UE to measure signals and receives path information from the UE.

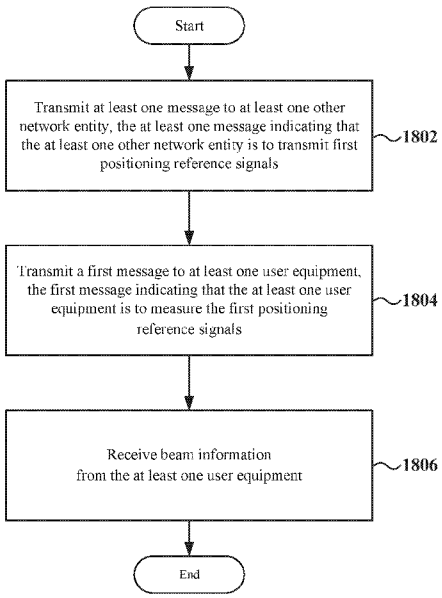


FIG. 18

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[Continued on next page]

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PATH INFORMATION BASED ON REFERENCE AND SENSING SIGNALS

TECHNICAL FIELD

[0001] The technology discussed below relates generally to wireless communication and, more particularly, to generating path information based on a sensing signal and a reference signal.

INTRODUCTION

[0002] Next-generation wireless communication systems (e.g., 5GS) may include a 5G core network and a 5G radio access network (RAN), such as a New Radio (NR)-RAN. The NR-RAN supports communication via one or more cells. For example, a wireless communication device such as a user equipment (UE) may access a first cell of a first base station (BS) such as a gNB and/or access a second cell of a second base station.

[0003] A base station may schedule access to a cell to support access by multiple wireless communication devices. For example, a base station may allocate different resources (e.g., time domain and frequency domain resources) for different wireless communication devices operating within a cell of the base station.

BRIEF SUMMARY OF SOME EXAMPLES

[0004] The following presents a summary of one or more aspects of the present disclosure, in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated features of the disclosure and is intended neither to identify key or critical elements of all aspects of the disclosure nor to delineate the scope of any or all aspects of the disclosure. Its sole purpose is to present some concepts of one or more aspects of the disclosure in a form as a prelude to the more detailed description that is presented later.

[0005] In some examples, a user equipment may include a transceiver, and a processor coupled to the transceiver. The processor may be configured to receive a first reference signal from a first network entity. The processor may also be configured to sense at least one first object to provide a first sensing signal. The processor may further be configured to transmit path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

[0006] In some examples, a method for wireless communication at a user equipment is disclosed. The method may include receiving a first reference signal from a first network

entity. The method may also include sensing at least one first object to provide a first sensing signal. The method may further include transmitting path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

[0007] In some examples, a user equipment may include means for receiving a first reference signal from a first network entity. The user equipment may also include means for sensing at least one first object to provide a first sensing signal. The user equipment may further include means for transmitting path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

[0008] In some examples, a non-transitory computer-readable medium has stored therein instructions executable by one or more processors of a user equipment to receive a first reference signal from a first network entity. The computer-readable medium may also have stored therein instructions executable by one or more processors of the user equipment to sense at least one first object to provide a first sensing signal. The computer-readable medium may further have stored therein instructions executable by one or more processors of the user equipment to transmit path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

[0009] In some examples, a first network entity may include a transceiver and a processor coupled to the transceiver. The processor may be configured to transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals. The processor may also be configured to transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals. The processor may further be configured to receive path information from the at least one user equipment.

[0010] In some examples, a method for wireless communication at a first network entity is disclosed. The method may include transmitting at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals. The method may also include transmitting a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals. The method may further include receiving path information from the at least one user equipment.

[0011] In some examples, a first network entity may include means for transmitting at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals. The first network entity may also include means for transmitting a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals. The first network entity may further include means for receiving path information from the at least one user equipment.

[0012] In some examples, a non-transitory computer-readable medium has stored therein instructions executable by one or more processors of a first network entity to transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals. The computer-readable medium may also have stored therein instructions executable by one or more processors of the first network entity to transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals. The computer-readable medium may further have stored therein instructions executable by one or more processors of the first network entity to receive path information from the at least one user equipment.

[0013] These and other aspects of the disclosure will become more fully understood upon a review of the detailed description, which follows. Other aspects, features, and examples of the present disclosure will become apparent to those of ordinary skill in the art, upon reviewing the following description of specific, example aspects of the present disclosure in conjunction with the accompanying figures. While features of the present disclosure may be discussed relative to certain examples and figures below, all examples of the present disclosure can include one or more of the advantageous features discussed herein. In other words, while one or more examples may be discussed as having certain advantageous features, one or more of such features may also be used in accordance with the various examples of the disclosure discussed herein. In similar fashion, while example aspects may be discussed below as device, system, or method examples it should be understood that such example aspects can be implemented in various devices, systems, and methods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a schematic illustration of a wireless communication system according to some aspects.

[0015] FIG. 2 is a conceptual illustration of an example of a radio access network according to some aspects.

[0016] FIG. 3 is a diagram providing a high-level illustration of one example of a configuration of a disaggregated base station according to some aspects.

[0017] FIG. 4 is a schematic illustration of wireless resources in an air interface utilizing orthogonal frequency divisional multiplexing (OFDM) according to some aspects.

[0018] FIG. 5 is a conceptual illustration of an example of a wireless communication network employing sidelink communication according to some aspects.

[0019] FIG. 6 is a conceptual illustration of an example of sensing and radio frequency communication in a vehicle according to some aspects.

[0020] FIG. 7 is a conceptual illustration of an example of beam blockage prediction according to some aspects.

[0021] FIG. 8 is a block diagram of an example of a system for beam blockage prediction according to some aspects.

[0022] FIG. 9 is a schematic illustration of relative positions of devices in a network according to some aspects.

[0023] FIG. 10 is a block diagram of an example of a system for providing beam information according to some aspects.

[0024] FIG. 11 is a signaling diagram illustrating an example of signaling associated with the exchange of path information according to some aspects.

[0025] FIG. 12 is a signaling diagram illustrating another example of signaling associated with the exchange of beam information according to some aspects.

[0026] FIG. 13 is a block diagram conceptually illustrating an example of a hardware implementation for a user equipment employing a processing system according to some aspects.

[0027] FIG. 14 is a flow chart illustrating an example wireless communication method involving the communication of path information according to some aspects.

[0028] FIG. 15 is a flow chart illustrating an example wireless communication method involving the communication of beam information according to some aspects.

[0029] FIG. 16 is a block diagram conceptually illustrating an example of a hardware implementation for a network entity employing a processing system according to some aspects.

[0030] FIG. 17 is a flow chart illustrating an example wireless communication method involving positioning signals according to some aspects.

[0031] FIG. 18 is a flow chart illustrating another example wireless communication method involving positioning signals according to some aspects.

DETAILED DESCRIPTION

[0032] 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.

[0033] While aspects and examples are described in this application by illustration to some examples, those skilled in the art will understand that additional implementations and use cases may come about in many different arrangements and scenarios. Innovations described herein may be implemented across many differing platform types, devices, systems, shapes, sizes, and packaging arrangements. For example, aspects and/or uses may come about via integrated chip examples and other non-module-component based devices (e.g., end-user devices, vehicles, communication devices, computing devices, industrial equipment, retail/purchasing devices, medical devices, artificial intelligence-enabled (AI-enabled) devices, etc.). While some examples may or may not be specifically directed to use cases or applications, a wide assortment of applicability of described innovations may occur. Implementations may range a spectrum from chip-level or modular components to non-modular, non-chip-level implementations and further to aggregate, distributed, or original equipment manufacturer (OEM) devices or systems incorporating one or more aspects of the described innovations. In some practical settings, devices incorporating described aspects and features may also necessarily include additional components and features for implementation and practice of claimed and described examples. For example, transmission and reception of wireless signals

necessarily includes a number of components for analog and digital purposes (e.g., hardware components including antenna, radio frequency (RF) chains, power amplifiers, modulators, buffer, processor(s), interleaver, adders/summers, etc.). It is intended that innovations described herein may be practiced in a wide variety of devices, chip-level components, systems, distributed arrangements, disaggregated arrangements (e.g., base station and/or UE), end-user devices, etc., of varying sizes, shapes, and constitution.

[0034] Various aspects of the disclosure relate to path information for wireless communication. In some examples, a user equipment (UE) transmits path information to a network entity, where the path information may be based on signals received at the UE and objects sensed at the UE. In some examples, the path information relates to one or more signal paths between the UE and the network entity. For example, the path information may indicate a pathloss or a channel impulse response associated with a signal path. In some examples, the path information relates to one or more wireless communication beams between the UE and the network entity. For example, the path information may indicate at least one preferred beam and/or at least one restricted beam.

[0035] In some examples, a UE identifies, within the UE's sensed field-of-view (FoV), a line of sight (LoS) to a serving network entity. The UE may then determine (e.g., predict) whether this LoS or a nearby area will be blocked by another object in the UE's FoV. Based on this determination, the UE may generate path information indicative of one or more wireless communication beams between the UE and the network entity that are predicted to be blocked (e.g., at least one non-preferred beam) and/or one or more wireless communication beams between the UE and the network entity that are predicted to not be blocked (e.g., at least one preferred beam). Upon receiving this path information, the network entity may schedule communication between the UE and the network entity accordingly (e.g., schedule the communication on at least one preferred beam).

[0036] In some examples, a UE measures signals received at the UE, senses objects within the UE's FoV, and sends path information based on the measurements and sensing to a network entity. The network entity may then train a neural network based on the path information received from the UE and send corresponding neural network information to the UE. The UE may then generate beam information based on this neural network information. For example, a neural network at the UE may generate beam information indicative of one or more wireless communication beams between the UE and the network entity that are predicted to be blocked (e.g., at least one non-preferred beam) and/or one or more wireless communication beams between the UE and the network entity that are

predicted to not be blocked (e.g., at least one preferred beam). Upon receiving this beam information, the network entity may schedule communication between the UE and the network entity accordingly (e.g., schedule the communication on at least one preferred beam).

[0037] In some examples, a UE measures signals received at the UE, senses objects within the UE's FoV, and sends path information based on the measurements and sensing to a network entity. The network entity may then generate beam information based on the received path information. For example, the network entity may generate beam information indicative of one or more wireless communication beams between the UE and the network entity that are predicted to be blocked (e.g., at least one non-preferred beam) and/or one or more wireless communication beams between the UE and the network entity that are predicted to not be blocked (e.g., at least one preferred beam).

[0038] In some examples, a first network entity configures a UE to measure signals from one or more network entities. For example, the first network entity may configure itself and at least one other network entity to transmit positioning reference signals, and the first network entity may instruct the UE to measure these positioning reference signals. The UE may then generate path information based, at least in part, on these positioning reference signals, and send the path information to the network entity.

[0039] The various concepts presented throughout this disclosure may be implemented across a broad variety of telecommunication systems, network architectures, and communication standards. Referring now to FIG. 1, as an illustrative example without limitation, various aspects of the present disclosure are illustrated with reference to a wireless communication system 100. The wireless communication system 100 includes three interacting domains: a core network 102, a radio access network (RAN) 104, and a user equipment (UE) 106. By virtue of the wireless communication system 100, the UE 106 may be enabled to carry out data communication with an external data network 110, such as (but not limited to) the Internet.

[0040] The RAN 104 may implement any suitable wireless communication technology or technologies to provide radio access to the UE 106. As one example, the RAN 104 may operate according to 3rd Generation Partnership Project (3GPP) New Radio (NR) specifications, often referred to as 5G. As another example, the RAN 104 may operate under a hybrid of 5G NR and Evolved Universal Terrestrial Radio Access Network (eUTRAN) standards, often referred to as Long-Term Evolution (LTE). The 3GPP refers to this hybrid RAN as a next-generation RAN, or NG-RAN. In another example, the RAN

104 may operate according to both the LTE and 5G NR standards. Of course, many other examples may be utilized within the scope of the present disclosure.

[0041] As illustrated, the RAN 104 includes a plurality of base stations 108. Broadly, a base station is a network element in a radio access network responsible for radio transmission and reception in one or more cells to or from a UE. In different technologies, standards, or contexts, a base station may variously be referred to by those skilled in the art as a base transceiver station (BTS), a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), an access point (AP), a Node B (NB), an eNode B (eNB), a gNode B (gNB), a transmission and reception point (TRP), or some other suitable terminology. In some examples, a base station may include two or more TRPs that may be collocated or non-collocated. Each TRP may communicate on the same or different carrier frequency within the same or different frequency band. In examples where the RAN 104 operates according to both the LTE and 5G NR standards, one of the base stations 108 may be an LTE base station, while another base station may be a 5G NR base station.

[0042] The radio access network 104 is further illustrated supporting wireless communication for multiple mobile apparatuses. A mobile apparatus may be referred to as user equipment (UE) 106 in 3GPP standards, but may also be referred to by those skilled in the art as a mobile station (MS), a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal (AT), a mobile terminal, a wireless terminal, a remote terminal, a handset, a terminal, a user agent, a mobile client, a client, or some other suitable terminology. A UE 106 may be an apparatus that provides a user with access to network services. In examples where the RAN 104 operates according to both the LTE and 5G NR standards, the UE 106 may be an Evolved-Universal Terrestrial Radio Access Network – New Radio dual connectivity (EN-DC) UE that is capable of simultaneously connecting to an LTE base station and an NR base station to receive data packets from both the LTE base station and the NR base station.

[0043] Within the present document, a mobile apparatus need not necessarily have a capability to move, and may be stationary. The term mobile apparatus or mobile device broadly refers to a diverse array of devices and technologies. UEs may include a number of hardware structural components sized, shaped, and arranged to help in communication; such components can include antennas, antenna arrays, RF chains, amplifiers, one or

more processors, etc., electrically coupled to each other. For example, some non-limiting examples of a mobile apparatus include a mobile, a cellular (cell) phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal computer (PC), a notebook, a netbook, a smartbook, a tablet, a personal digital assistant (PDA), and a broad array of embedded systems, e.g., corresponding to an Internet of Things (IoT).

[0044] A mobile apparatus may additionally be an automotive or other transportation vehicle, a remote sensor or actuator, a robot or robotics device, a satellite radio, a global positioning system (GPS) device, an object tracking device, a drone, a multi-copter, a quad-copter, a remote control device, a consumer and/or wearable device, such as eyewear, a wearable camera, a virtual reality device, a smart watch, a health or fitness tracker, a digital audio player (e.g., MP3 player), a camera, a game console, etc. A mobile apparatus may additionally be a digital home or smart home device such as a home audio, video, and/or multimedia device, an appliance, a vending machine, intelligent lighting, a home security system, a smart meter, etc. A mobile apparatus may additionally be a smart energy device, a security device, a solar panel or solar array, a municipal infrastructure device controlling electric power (e.g., a smart grid), lighting, water, etc., an industrial automation and enterprise device, a logistics controller, agricultural equipment, etc. Still further, a mobile apparatus may provide for connected medicine or telemedicine support, i.e., health care at a distance. Telehealth devices may include telehealth monitoring devices and telehealth administration devices, whose communication may be given preferential treatment or prioritized access over other types of information, e.g., in terms of prioritized access for transport of critical service data, and/or relevant QoS for transport of critical service data.

[0045] Wireless communication between a RAN 104 and a UE 106 may be described as utilizing an air interface. Transmissions over the air interface from a base station (e.g., base station 108) to one or more UEs (e.g., UE 106) may be referred to as downlink (DL) transmission. In some examples, the term downlink may refer to a point-to-multipoint transmission originating at a base station (e.g., base station 108). Another way to describe this point-to-multipoint transmission scheme may be to use the term broadcast channel multiplexing. Transmissions from a UE (e.g., UE 106) to a base station (e.g., base station 108) may be referred to as uplink (UL) transmissions. In some examples, the term uplink may refer to a point-to-point transmission originating at a UE (e.g., UE 106).

[0046] In some examples, access to the air interface may be scheduled, wherein a scheduling entity (e.g., a base station 108) or some other type of network entity allocates

resources for communication among some or all devices and equipment within its service area or cell. Within the present disclosure, as discussed further below, the scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more scheduled entities (e.g., UEs). That is, for scheduled communication, a plurality of UEs 106, which may be scheduled entities, may utilize resources allocated by a scheduling entity (e.g., a base station 108).

[0047] Base stations 108 are not the only entities that may function as scheduling entities. That is, in some examples, a UE may function as a scheduling entity, scheduling resources for one or more scheduled entities (e.g., one or more other UEs). For example, UEs may communicate with other UEs in a peer-to-peer or device-to-device fashion and/or in a relay configuration.

[0048] As illustrated in FIG. 1, a scheduling entity (e.g., a base station 108) may broadcast downlink traffic 112 to one or more scheduled entities (e.g., a UE 106). Broadly, the scheduling entity is a node or device responsible for scheduling traffic in a wireless communication network, including the downlink traffic 112 and, in some examples, uplink traffic 116 and/or uplink control information 118 from one or more scheduled entities to the scheduling entity. On the other hand, the scheduled entity is a node or device that receives downlink control information 114, including but not limited to scheduling information (e.g., a grant), synchronization or timing information, or other control information from another entity in the wireless communication network such as the scheduling entity.

[0049] In addition, the uplink control information 118, downlink control information 114, downlink traffic 112, and/or uplink traffic 116 may be time-divided into frames, subframes, slots, and/or symbols. As used herein, a symbol may refer to a unit of time that, in an orthogonal frequency division multiplexed (OFDM) waveform, carries one resource element (RE) per sub-carrier. A slot may carry 7 or 14 OFDM symbols in some examples. A subframe may refer to a duration of 1 millisecond (ms). Multiple subframes or slots may be grouped together to form a single frame or radio frame. Within the present disclosure, a frame may refer to a predetermined duration (e.g., 10 ms) for wireless transmissions, with each frame consisting of, for example, 10 subframes of 1 ms each. Of course, these definitions are not required, and any suitable scheme for organizing waveforms may be utilized, and various time divisions of the waveform may have any suitable duration.

[0050] In general, base stations 108 may include a backhaul interface for communication with a backhaul 120 of the wireless communication system. The backhaul 120 may provide a link between a base station 108 and the core network 102. Further, in some examples, a backhaul network may provide interconnection between the respective base stations 108. Various types of backhaul interfaces may be employed, such as a direct physical connection, a virtual network, or the like using any suitable transport network.

[0051] The core network 102 may be a part of the wireless communication system 100, and may be independent of the radio access technology used in the RAN 104. In some examples, the core network 102 may be configured according to 5G standards (e.g., 5GC). In other examples, the core network 102 may be configured according to a 4G evolved packet core (EPC), or any other suitable standard or configuration.

[0052] Referring now to FIG. 2, by way of example and without limitation, a schematic illustration of a radio access network (RAN) 200 is provided. In some examples, the RAN 200 may be the same as the RAN 104 described above and illustrated in FIG. 1.

[0053] The geographic area covered by the RAN 200 may be divided into cellular regions (cells) that can be uniquely identified by a user equipment (UE) based on an identification broadcasted from one access point or base station. FIG. 2 illustrates cells 202, 204, 206, and 208, each of which may include one or more sectors (not shown). A sector is a sub-area of a cell. All sectors within one cell are served by the same base station. A radio link within a sector can be identified by a single logical identification belonging to that sector. In a cell that is divided into sectors, the multiple sectors within a cell can be formed by groups of antennas with each antenna responsible for communication with UEs in a portion of the cell.

[0054] Various base station arrangements can be utilized. For example, in FIG. 2, two base stations 210 and 212 are shown in cells 202 and 204; and a base station 214 is shown controlling a remote radio head (RRH) 216 in cell 206. That is, a base station can have an integrated antenna or can be connected to an antenna or RRH by feeder cables. In the illustrated example, the cells 202, 204, and 206 may be referred to as macrocells, as the base stations 210, 212, and 214 support cells having a large size. Further, a base station 218 is shown in the cell 208, which may overlap with one or more macrocells. In this example, the cell 208 may be referred to as a small cell (e.g., a microcell, picocell, femtocell, home base station, home Node B, home eNode B, etc.), as the base station 218 supports a cell having a relatively small size. Cell sizing can be done according to system design as well as component constraints.

[0055] It is to be understood that the RAN 200 may include any number of wireless base stations and cells. Further, a relay node may be deployed to extend the size or coverage area of a given cell. The base stations 210, 212, 214, 218 provide wireless access points to a core network for any number of mobile apparatuses. In some examples, the base stations 210, 212, 214, and/or 218 may be the same as the base station/scheduling entity described above and illustrated in FIG. 1.

[0056] FIG. 2 further includes an unmanned aerial vehicle (UAV) 220, which may be a drone or quadcopter. The UAV 220 may be configured to function as a base station, or more specifically as a mobile base station. That is, in some examples, a cell may not necessarily be stationary, and the geographic area of the cell may move according to the location of a mobile base station, such as the UAV 220.

[0057] Within the RAN 200, the cells may include UEs that may be in communication with one or more sectors of each cell. Further, each base station 210, 212, 214, and 218 may be configured to provide an access point to a core network 102 (see FIG. 1) for all the UEs in the respective cells. For example, UEs 222 and 224 may be in communication with base station 210; UEs 226 and 228 may be in communication with base station 212; UEs 230 and 232 may be in communication with base station 214 by way of RRH 216; and UE 234 may be in communication with base station 218. In some examples, the UEs 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, and/or 242 may be the same as the UE/scheduled entity described above and illustrated in FIG. 1. In some examples, the UAV 220 (e.g., the quadcopter) can be a mobile network node and may be configured to function as a UE. For example, the UAV 220 may operate within cell 202 by communicating with base station 210.

[0058] In a further aspect of the RAN 200, sidelink signals may be used between UEs without necessarily relying on scheduling or control information from a base station. Sidelink communication may be utilized, for example, in a device-to-device (D2D) network, peer-to-peer (P2P) network, vehicle-to-vehicle (V2V) network, vehicle-to-everything (V2X) network, and/or other suitable sidelink network. For example, two or more UEs (e.g., UEs 238, 240, and 242) may communicate with each other using sidelink signals 237 without relaying that communication through a base station. In some examples, the UEs 238, 240, and 242 may each function as a scheduling entity or transmitting sidelink device and/or a scheduled entity or a receiving sidelink device to schedule resources and communicate sidelink signals 237 therebetween without relying on scheduling or control information from a base station. In other examples, two or more

UEs (e.g., UEs 226 and 228) within the coverage area of a base station (e.g., base station 212) may also communicate sidelink signals 227 over a direct link (sidelink) without conveying that communication through the base station 212. In this example, the base station 212 may allocate resources to the UEs 226 and 228 for the sidelink communication.

[0059] In the RAN 200, the ability for a UE to communicate while moving, independent of its location, is referred to as mobility. The various physical channels between the UE and the radio access network are generally set up, maintained, and released under the control of an access and mobility management function (AMF, not illustrated, part of the core network 102 in FIG. 1), which may include a security context management function (SCMF) that manages the security context for both the control plane and the user plane functionality, and a security anchor function (SEAF) that performs authentication.

[0060] A RAN 200 may utilize DL-based mobility or UL-based mobility to enable mobility and handovers (i.e., the transfer of a UE's connection from one radio channel to another). In a network configured for DL-based mobility, during a call with a scheduling entity, or at any other time, a UE may monitor various parameters of the signal from its serving cell as well as various parameters of neighboring cells. Depending on the quality of these parameters, the UE may maintain communication with one or more of the neighboring cells. During this time, if the UE moves from one cell to another, or if signal quality from a neighboring cell exceeds that from the serving cell for a given amount of time, the UE may undertake a handoff or handover from the serving cell to the neighboring (target) cell. For example, UE 224 (illustrated as a vehicle, although any suitable form of UE may be used) may move from the geographic area corresponding to its serving cell (e.g., the cell 202) to the geographic area corresponding to a neighbor cell (e.g., the cell 206). When the signal strength or quality from the neighbor cell exceeds that of the serving cell for a given amount of time, the UE 224 may transmit a reporting message to its serving base station (e.g., the base station 210) indicating this condition. In response, the UE 224 may receive a handover command, and the UE may undergo a handover to the cell 206.

[0061] In a network configured for UL-based mobility, UL reference signals from each UE may be utilized by the network to select a serving cell for each UE. In some examples, the base stations 210, 212, and 214/216 may broadcast unified synchronization signals (e.g., unified Primary Synchronization Signals (PSSs), unified Secondary Synchronization Signals (SSSs) and unified Physical Broadcast Channels (PBCH)). The

UEs 222, 224, 226, 228, 230, and 232 may receive the unified synchronization signals, derive the carrier frequency and slot timing from the synchronization signals, and in response to deriving timing, transmit an uplink pilot or reference signal. The uplink pilot signal transmitted by a UE (e.g., UE 224) may be concurrently received by two or more cells (e.g., base stations 210 and 214/216) within the RAN 200. Each of the cells may measure a strength of the pilot signal, and the radio access network (e.g., one or more of the base stations 210 and 214/216 and/or a central node within the core network) may determine a serving cell for the UE 224. As the UE 224 moves through the RAN 200, the network may continue to monitor the uplink pilot signal transmitted by the UE 224. When the signal strength or quality of the pilot signal measured by a neighboring cell exceeds that of the signal strength or quality measured by the serving cell, the RAN 200 may handover the UE 224 from the serving cell to the neighboring cell, with or without informing the UE 224.

[0062] Although the synchronization signal transmitted by the base stations 210, 212, and 214/216 may be unified, the synchronization signal may not identify a particular cell, but rather may identify a zone of multiple cells operating on the same frequency and/or with the same timing. The use of zones in 5G networks or other next generation communication networks enables the uplink-based mobility framework and improves the efficiency of both the UE and the network, since the number of mobility messages that need to be exchanged between the UE and the network may be reduced.

[0063] In various implementations, the air interface in the RAN 200 may utilize licensed spectrum, unlicensed spectrum, or shared spectrum. Licensed spectrum provides for exclusive use of a portion of the spectrum, generally by virtue of a mobile network operator purchasing a license from a government regulatory body. Unlicensed spectrum provides for shared use of a portion of the spectrum without the need for a government-granted license. While compliance with some technical rules is generally still required to access unlicensed spectrum, generally, any operator or device may gain access. Shared spectrum may fall between licensed and unlicensed spectrum, wherein technical rules or limitations may be required to access the spectrum, but the spectrum may still be shared by multiple operators and/or multiple radio access technologies (RATs). For example, the holder of a license for a portion of licensed spectrum may provide licensed shared access (LSA) to share that spectrum with other parties, e.g., with suitable licensee-determined conditions to gain access.

[0064] The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR, two initial operating bands have been identified as frequency range designations FR1 (410 MHz - 7.125 GHz) and FR2 (24.25 GHz - 52.6 GHz). It should be understood that although a portion of FR1 is greater than 6 GHz, FR1 is often referred to (interchangeably) as a "Sub-6 GHz" band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a "millimeter wave" band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHz - 300 GHz) which is identified by the International Telecommunications Union (ITU) as a "millimeter wave" band.

[0065] The frequencies between FR1 and FR2 are often referred to as mid-band frequencies. Recent 5G NR studies have identified an operating band for these mid-band frequencies as frequency range designation FR3 (7.125 GHz - 24.25 GHz). Frequency bands falling within FR3 may inherit FR1 characteristics and/or FR2 characteristics, and thus may effectively extend features of FR1 and/or FR2 into mid-band frequencies. In addition, higher frequency bands are currently being explored to extend 5G NR operation beyond 52.6 GHz. For example, three higher operating bands have been identified as frequency range designations FR4-a or FR4-1 (52.6 GHz - 71 GHz), FR4 (52.6 GHz - 114.25 GHz), and FR5 (114.25 GHz - 300 GHz). Each of these higher frequency bands falls within the EHF band.

[0066] With the above aspects in mind, unless specifically stated otherwise, it should be understood that the term "sub-6 GHz" or the like if used herein may broadly represent frequencies that may be less than 6 GHz, may be within FR1, or may include mid-band frequencies. Further, unless specifically stated otherwise, it should be understood that the term "millimeter wave" or the like if used herein may broadly represent frequencies that may include mid-band frequencies, may be within FR2, FR4, FR4-a or FR4-1, and/or FR5, or may be within the EHF band.

[0067] The air interface in the RAN 200 may utilize one or more multiplexing and multiple access algorithms to enable simultaneous communication of the various devices. For example, 5G NR specifications provide multiple access for UL transmissions from UEs 222 and 224 to base station 210, and for multiplexing for DL transmissions from base station 210 to one or more UEs 222 and 224, utilizing orthogonal frequency division multiplexing (OFDM) with a cyclic prefix (CP). In addition, for UL transmissions, 5G NR specifications provide support for discrete Fourier transform-spread-OFDM (DFT-s-

OFDM) with a CP (also referred to as single-carrier FDMA (SC-FDMA)). However, within the scope of the present disclosure, multiplexing and multiple access are not limited to the above schemes, and may be provided utilizing time division multiple access (TDMA), code division multiple access (CDMA), frequency division multiple access (FDMA), sparse code multiple access (SCMA), resource spread multiple access (RSMA), or other suitable multiple access schemes. Further, multiplexing DL transmissions from the base station 210 to UEs 222 and 224 may be provided utilizing time division multiplexing (TDM), code division multiplexing (CDM), frequency division multiplexing (FDM), orthogonal frequency division multiplexing (OFDM), sparse code multiplexing (SCM), or other suitable multiplexing schemes.

[0068] The air interface in the RAN 200 may further utilize one or more duplexing algorithms. Duplex refers to a point-to-point communication link where both endpoints can communicate with one another in both directions. Full-duplex means both endpoints can simultaneously communicate with one another. Half-duplex means only one endpoint can send information to the other at a time. Half-duplex emulation is frequently implemented for wireless links utilizing time division duplex (TDD). In TDD, transmissions in different directions on a given channel are separated from one another using time division multiplexing. That is, at some times the channel is dedicated for transmissions in one direction, while at other times the channel is dedicated for transmissions in the other direction, where the direction may change very rapidly, e.g., several times per slot. In a wireless link, a full-duplex channel generally relies on physical isolation of a transmitter and receiver, and suitable interference cancelation technologies. Full-duplex emulation is frequently implemented for wireless links by utilizing frequency division duplex (FDD) or spatial division duplex (SDD). In FDD, transmissions in different directions operate at different carrier frequencies. In SDD, transmissions in different directions on a given channel are separate from one another using spatial division multiplexing (SDM). In other examples, full-duplex communication may be implemented within unpaired spectrum (e.g., within a single carrier bandwidth), where transmissions in different directions occur within different sub-bands of the carrier bandwidth. This type of full-duplex communication may be referred to as sub-band full-duplex (SBFD), cross-division duplex (xDD), or flexible duplex.

[0069] Deployment of communication systems, such as 5G new radio (NR) systems, may be arranged in multiple manners with various components or constituent parts. In a 5G NR system, or network, a network node, a network entity, a mobility element of a

network, a radio access network (RAN) node, a core network node, a network element, or a network equipment, such as a base station (BS), or one or more units (or one or more components) performing base station functionality, may be implemented in an aggregated or disaggregated architecture. For example, a BS (such as a Node B (NB), evolved NB (eNB), NR BS, 5G NB, access point (AP), a transmit receive point (TRP), or a cell, etc.) may be implemented as an aggregated base station (also known as a standalone BS or a monolithic BS) or a disaggregated base station.

[0070] An aggregated base station may be configured to utilize a radio protocol stack that is physically or logically integrated within a single RAN node. A disaggregated base station may be configured to utilize a protocol stack that is physically or logically distributed among two or more units (such as one or more central or centralized units (CUs), one or more distributed units (DUs), or one or more radio units (RUs)). In some aspects, a CU may be implemented within a RAN node, and one or more DUs may be co-located with the CU, or alternatively, may be geographically or virtually distributed throughout one or multiple other RAN nodes. The DUs may be implemented to communicate with one or more RUs. Each of the CUs, the DUs, and the RUs also can be implemented as virtual units, i.e., a virtual central unit (VCU), a virtual distributed unit (VDU), or a virtual radio unit (VRU).

[0071] Base station-type operation or network design may consider aggregation characteristics of base station functionality. For example, disaggregated base stations may be utilized in an integrated access backhaul (IAB) network, an open radio access network (O-RAN (such as the network configuration sponsored by the O-RAN Alliance)), or a virtualized radio access network (vRAN, also known as a cloud radio access network (C-RAN)). Disaggregation may include distributing functionality across two or more units at various physical locations, as well as distributing functionality for at least one unit virtually, which can enable flexibility in network design. The various units of the disaggregated base station, or disaggregated RAN architecture, can be configured for wired or wireless communication with at least one other unit.

[0072] FIG. 3 shows a diagram illustrating an example disaggregated base station 300 architecture. The disaggregated base station 300 architecture may include one or more central units (CUs) 310 that can communicate directly with a core network 320 via a backhaul link, or indirectly with the core network 320 through one or more disaggregated base station units (such as a Near-Real Time (Near-RT) RAN Intelligent Controller (RIC) 325 via an E2 link, or a Non-Real Time (Non-RT) RIC 315 associated with a Service

Management and Orchestration (SMO) Framework 305, or both). A CU 310 may communicate with one or more distributed units (DUs) 330 via respective midhaul links, such as an F1 interface. The DUs 330 may communicate with one or more radio units (RUs) 340 via respective fronthaul links. The RUs 340 may communicate with respective UEs 350 via one or more radio frequency (RF) access links. In some implementations, the UE 350 may be simultaneously served by multiple RUs 340.

[0073] Each of the units, i.e., the CUs 310, the DUs 330, the RUs 340, as well as the Near-RT RICs 325, the Non-RT RICs 315 and the SMO Framework 305, may include one or more interfaces or be coupled to one or more interfaces configured to receive or transmit signals, data, or information (collectively, signals) via a wired or wireless transmission medium. Each of the units, or an associated processor or controller providing instructions to the communication interfaces of the units, can be configured to communicate with one or more of the other units via the transmission medium. For example, the units can include a wired interface configured to receive or transmit signals over a wired transmission medium to one or more of the other units. Additionally, the units can include a wireless interface, which may include a receiver, a transmitter or transceiver (such as a radio frequency (RF) transceiver), configured to receive or transmit signals, or both, over a wireless transmission medium to one or more of the other units.

[0074] In some aspects, the CU 310 may host one or more higher layer control functions. Such control functions can include radio resource control (RRC), packet data convergence protocol (PDCP), service data adaptation protocol (SDAP), or the like. Each control function can be implemented with an interface configured to communicate signals with other control functions hosted by the CU 310. The CU 310 may be configured to handle user plane functionality (i.e., Central Unit – User Plane (CU-UP)), control plane functionality (i.e., Central Unit – Control Plane (CU-CP)), or a combination thereof. In some implementations, the CU 310 can be logically split into one or more CU-UP units and one or more CU-CP units. The CU-UP unit can communicate bidirectionally with the CU-CP unit via an interface, such as the E1 interface when implemented in an O-RAN configuration. The CU 310 can be implemented to communicate with the distributed unit (DU) 330, as necessary, for network control and signaling.

[0075] The DU 330 may correspond to a logical unit that includes one or more base station functions to control the operation of one or more RUs 340. In some aspects, the DU 330 may host one or more of a radio link control (RLC) layer, a medium access control (MAC) layer, and one or more high physical (PHY) layers (such as modules for

forward error correction (FEC) encoding and decoding, scrambling, modulation and demodulation, or the like) depending, at least in part, on a functional split, such as those defined by the 3rd Generation Partnership Project (3GPP). In some aspects, the DU 330 may further host one or more low PHY layers. Each layer (or module) can be implemented with an interface configured to communicate signals with other layers (and modules) hosted by the DU 330, or with the control functions hosted by the CU 310.

[0076] Lower-layer functionality can be implemented by one or more RUs 340. In some deployments, an RU 340, controlled by a DU 330, may correspond to a logical node that hosts RF processing functions, or low-PHY layer functions (such as performing fast Fourier transform (FFT), inverse FFT (iFFT), digital beamforming, physical random access channel (PRACH) extraction and filtering, or the like), or both, based at least in part on the functional split, such as a lower layer functional split. In such an architecture, the RU(s) 340 can be implemented to handle over the air (OTA) communication with one or more UEs 350. In some implementations, real-time and non-real-time aspects of control and user plane communication with the RU(s) 340 can be controlled by the corresponding DU 330. In some scenarios, this configuration can enable the DU(s) 330 and the CU 310 to be implemented in a cloud-based RAN architecture, such as a vRAN architecture.

[0077] The SMO Framework 305 may be configured to support RAN deployment and provisioning of non-virtualized and virtualized network elements. For non-virtualized network elements, the SMO Framework 305 may be configured to support the deployment of dedicated physical resources for RAN coverage requirements which may be managed via an operations and maintenance interface (such as an O1 interface). For virtualized network elements, the SMO Framework 305 may be configured to interact with a cloud computing platform (such as an open cloud (O-Cloud) 390) to perform network element life cycle management (such as to instantiate virtualized network elements) via a cloud computing platform interface (such as an O2 interface). Such virtualized network elements can include, but are not limited to, CUs 310, DUs 330, RUs 340 and Near-RT RICs 325. In some implementations, the SMO Framework 305 can communicate with a hardware aspect of a 4G RAN, such as an open eNB (O-eNB) 311, via an O1 interface. Additionally, in some implementations, the SMO Framework 305 can communicate directly with one or more RUs 340 via an O1 interface. The SMO Framework 305 also may include a Non-RT RIC 315 configured to support functionality of the SMO Framework 305.

[0078] The Non-RT RIC 315 may be configured to include a logical function that enables non-real-time control and optimization of RAN elements and resources, Artificial Intelligence/Machine Learning (AI/ML) workflows including model training and updates, or policy-based guidance of applications/features in the Near-RT RIC 325. The Non-RT RIC 315 may be coupled to or communicate with (such as via an A1 interface) the Near-RT RIC 325. The Near-RT RIC 325 may be configured to include a logical function that enables near-real-time control and optimization of RAN elements and resources via data collection and actions over an interface (such as via an E2 interface) connecting one or more CUs 310, one or more DUs 330, or both, as well as an O-eNB, with the Near-RT RIC 325.

[0079] In some implementations, to generate AI/ML models to be deployed in the Near-RT RIC 325, the Non-RT RIC 315 may receive parameters or external enrichment information from external servers. Such information may be utilized by the Near-RT RIC 325 and may be received at the SMO Framework 305 or the Non-RT RIC 315 from non-network data sources or from network functions. In some examples, the Non-RT RIC 315 or the Near-RT RIC 325 may be configured to tune RAN behavior or performance. For example, the Non-RT RIC 315 may monitor long-term trends and patterns for performance and employ AI/ML models to perform corrective actions through the SMO Framework 305 (such as reconfiguration via O1) or via creation of RAN management policies (such as A1 policies).

[0080] Various aspects of the present disclosure will be described with reference to an OFDM waveform, an example of which is schematically illustrated in FIG. 4. It should be understood by those of ordinary skill in the art that the various aspects of the present disclosure may be applied to an SC-FDMA waveform in substantially the same way as described herein below. That is, while some examples of the present disclosure may focus on an OFDM link for clarity, it should be understood that the same principles may be applied as well to SC-FDMA waveforms.

[0081] Referring now to FIG. 4, an expanded view of an example subframe 402 is illustrated, showing an OFDM resource grid. However, as those skilled in the art will readily appreciate, the physical (PHY) layer transmission structure for any particular application may vary from the example described here, depending on any number of factors. Here, time is in the horizontal direction with units of OFDM symbols; and frequency is in the vertical direction with units of subcarriers of the carrier.

[0082] The resource grid 404 may be used to schematically represent time-frequency resources for a given antenna port. In some examples, an antenna port is a logical entity used to map data streams to one or more antennas. Each antenna port may be associated with a reference signal (e.g., which may allow a receiver to distinguish data streams associated with the different antenna ports in a received transmission). An antenna port may be defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. Thus, a given antenna port may represent a specific channel model associated with a particular reference signal. In some examples, a given antenna port and sub-carrier spacing (SCS) may be associated with a corresponding resource grid (including REs as discussed above). Here, modulated data symbols from multiple-input-multiple-output (MIMO) layers may be combined and re-distributed to each of the antenna ports, then precoding is applied, and the precoded data symbols are applied to corresponding REs for OFDM signal generation and transmission via one or more physical antenna elements. In some examples, the mapping of an antenna port to a physical antenna may be based on beamforming (e.g., a signal may be transmitted on certain antenna ports to form a desired beam). Thus, a given antenna port may correspond to a particular set of beamforming parameters (e.g., signal phases and/or amplitudes).

[0083] In a MIMO implementation with multiple antenna ports available, a corresponding multiple number of resource grids 404 may be available for communication. The resource grid 404 is divided into multiple resource elements (REs) 406. An RE, which is 1 subcarrier × 1 symbol, is the smallest discrete part of the time–frequency grid, and contains a single complex value representing data from a physical channel or signal. Depending on the modulation utilized in a particular implementation, each RE may represent one or more bits of information. In some examples, a block of REs may be referred to as a physical resource block (PRB) or more simply a resource block (RB) 408, which contains any suitable number of consecutive subcarriers in the frequency domain. In one example, an RB may include 12 subcarriers, a number independent of the numerology used. In some examples, depending on the numerology, an RB may include any suitable number of consecutive OFDM symbols in the time domain. Within the present disclosure, it is assumed that a single RB such as the RB 408 entirely corresponds to a single direction of communication (either transmission or reception for a given device).

[0084] A set of continuous or discontinuous resource blocks may be referred to herein as a Resource Block Group (RBG), sub-band, or bandwidth part (BWP). A set of sub-bands or BWPs may span the entire bandwidth. Scheduling of scheduled entities (e.g., UEs) for downlink, uplink, or sidelink transmissions typically involves scheduling one or more resource elements 406 within one or more sub-bands or bandwidth parts (BWPs). Thus, a UE generally utilizes only a subset of the resource grid 404. In some examples, an RB may be the smallest unit of resources that can be allocated to a UE. Thus, the more RBs scheduled for a UE, and the higher the modulation scheme chosen for the air interface, the higher the data rate for the UE. The RBs may be scheduled by a scheduling entity, such as a base station (e.g., gNB, eNB, etc.), or may be self-scheduled by a UE implementing D2D sidelink communication.

[0085] In this illustration, the RB 408 is shown as occupying less than the entire bandwidth of the subframe 402, with some subcarriers illustrated above and below the RB 408. In a given implementation, the subframe 402 may have a bandwidth corresponding to any number of one or more RBs 408. Further, in this illustration, the RB 408 is shown as occupying less than the entire duration of the subframe 402, although this is merely one possible example.

[0086] Each 1 ms subframe 402 may consist of one or multiple adjacent slots. In the example shown in FIG. 4, one subframe 402 includes four slots 410, as an illustrative example. In some examples, a slot may be defined according to a specified number of OFDM symbols with a given cyclic prefix (CP) length. For example, a slot may include 7 or 14 OFDM symbols with a nominal CP. Additional examples may include mini-slots, sometimes referred to as shortened transmission time intervals (TTIs), having a shorter duration (e.g., one to three OFDM symbols). These mini-slots or shortened transmission time intervals (TTIs) may in some cases be transmitted occupying resources scheduled for ongoing slot transmissions for the same or for different UEs. Any number of resource blocks may be utilized within a subframe or slot.

[0087] An expanded view of one of the slots 410 illustrates the slot 410 including a control region 412 and a data region 414. In general, the control region 412 may carry control channels, and the data region 414 may carry data channels. Of course, a slot may contain all DL, all UL, or at least one DL portion and at least one UL portion. The structure illustrated in FIG. 4 is merely an example, and different slot structures may be utilized, and may include one or more of each of the control region(s) and data region(s).

[0088] Although not illustrated in FIG. 4, the various REs 406 within an RB 408 may be scheduled to carry one or more physical channels, including control channels, shared channels, data channels, etc. Other REs 406 within the RB 408 may also carry pilots or reference signals. These pilots or reference signals may provide for a receiving device to perform channel estimation of the corresponding channel, which may enable coherent demodulation/detection of the control and/or data channels within the RB 408.

[0089] In some examples, the slot 410 may be utilized for broadcast, multicast, groupcast, or unicast communication. For example, a broadcast, multicast, or groupcast communication may refer to a point-to-multipoint transmission by one device (e.g., a base station, UE, or other similar device) to other devices. Here, a broadcast communication is delivered to all devices, whereas a multicast or groupcast communication is delivered to multiple intended recipient devices. A unicast communication may refer to a point-to-point transmission by a one device to a single other device.

[0090] In an example of cellular communication over a cellular carrier via a Uu interface, for a DL transmission, the scheduling entity (e.g., a base station) may allocate one or more REs 406 (e.g., within the control region 412) to carry DL control information including one or more DL control channels, such as a physical downlink control channel (PDCCH), to one or more scheduled entities (e.g., UEs). The PDCCH carries downlink control information (DCI) including but not limited to power control commands (e.g., one or more open loop power control parameters and/or one or more closed loop power control parameters), scheduling information, a grant, and/or an assignment of REs for DL and UL transmissions. The PDCCH may further carry hybrid automatic repeat request (HARQ) feedback transmissions such as an acknowledgment (ACK) or negative acknowledgment (NACK). HARQ is a technique well-known to those of ordinary skill in the art, wherein the integrity of packet transmissions may be checked at the receiving side for accuracy, e.g., utilizing any suitable integrity checking mechanism, such as a checksum or a cyclic redundancy check (CRC). If the integrity of the transmission is confirmed, an ACK may be transmitted, whereas if not confirmed, a NACK may be transmitted. In response to a NACK, the transmitting device may send a HARQ retransmission, which may implement chase combining, incremental redundancy, etc.

[0091] The base station may further allocate one or more REs 406 (e.g., in the control region 412 or the data region 414) to carry other DL signals, such as a demodulation reference signal (DMRS); a phase-tracking reference signal (PT-RS); a channel state information (CSI) reference signal (CSI-RS); and a synchronization signal block (SSB).

SSBs may be broadcast at regular intervals based on a periodicity (e.g., 5, 10, 20, 30, 80, or 130 ms). An SSB includes a primary synchronization signal (PSS), a secondary synchronization signal (SSS), and a physical broadcast control channel (PBCH). A UE may utilize the PSS and SSS to achieve radio frame, subframe, slot, and symbol synchronization in the time domain, identify the center of the channel (system) bandwidth in the frequency domain, and identify the physical cell identity (PCI) of the cell.

[0092] The PBCH in the SSB may further include a master information block (MIB) that includes various system information, along with parameters for decoding a system information block (SIB). The SIB may be, for example, a SystemInformationType 1 (SIB1) that may include various additional (remaining) system information. The MIB and SIB1 together provide the minimum system information (SI) for initial access. Examples of system information transmitted in the MIB may include, but are not limited to, a subcarrier spacing (e.g., default downlink numerology), system frame number, a configuration of a PDCCH control resource set (CORESET) (e.g., PDCCH CORESET0), a cell barred indicator, a cell reselection indicator, a raster offset, and a search space for SIB1. Examples of remaining minimum system information (RMSI) transmitted in the SIB1 may include, but are not limited to, a random access search space, a paging search space, downlink configuration information, and uplink configuration information. A base station may transmit other system information (OSI) as well.

[0093] In an UL transmission, the UE may utilize one or more REs 406 to carry UL control information (UCI) including one or more UL control channels, such as a physical uplink control channel (PUCCH), to the scheduling entity. UCI may include a variety of packet types and categories, including pilots, reference signals, and information configured to enable or assist in decoding uplink data transmissions. Examples of uplink reference signals may include a sounding reference signal (SRS) and an uplink DMRS. In some examples, the UCI may include a scheduling request (SR), i.e., request for the scheduling entity to schedule uplink transmissions. Here, in response to the SR transmitted on the UCI, the scheduling entity may transmit downlink control information (DCI) that may schedule resources for uplink packet transmissions. UCI may also include HARQ feedback, channel state feedback (CSF), such as a CSI report, or any other suitable UCI.

[0094] In addition to control information, one or more REs 406 (e.g., within the data region 414) may be allocated for data traffic. Such data traffic may be carried on one or more traffic channels, such as, for a DL transmission, a physical downlink shared channel

(PDSCH); or for an UL transmission, a physical uplink shared channel (PUSCH). In some examples, one or more REs 406 within the data region 414 may be configured to carry other signals, such as one or more SIBs and DMRSs.

[0095] In an example of sidelink communication over a sidelink carrier via a proximity service (ProSe) PC5 interface, the control region 412 of the slot 410 may include a physical sidelink control channel (PSCCH) including sidelink control information (SCI) transmitted by an initiating (transmitting) sidelink device (e.g., a transmitting (Tx) V2X device or other Tx UE) towards a set of one or more other receiving sidelink devices (e.g., a receiving (Rx) V2X device or some other Rx UE). The data region 414 of the slot 410 may include a physical sidelink shared channel (PSSCH) including sidelink data traffic transmitted by the initiating (transmitting) sidelink device within resources reserved over the sidelink carrier by the transmitting sidelink device via the SCI. Other information may further be transmitted over various REs 406 within slot 410. For example, HARQ feedback information may be transmitted in a physical sidelink feedback channel (PSFCH) within the slot 410 from the receiving sidelink device to the transmitting sidelink device. In addition, one or more reference signals, such as a sidelink SSB, a sidelink CSI-RS, a sidelink SRS, and/or a sidelink positioning reference signal (PRS) may be transmitted within the slot 410.

[0096] These physical channels described above are generally multiplexed and mapped to transport channels for handling at the medium access control (MAC) layer. Transport channels carry blocks of information called transport blocks (TB). The transport block size (TBS), which may correspond to a number of bits of information, may be a controlled parameter, based on the modulation and coding scheme (MCS) and the number of RBs in a given transmission.

[0097] The channels or carriers described above with reference to FIGs. 1 - 4 are not necessarily all of the channels or carriers that may be utilized between a scheduling entity and scheduled entities, and those of ordinary skill in the art will recognize that other channels or carriers may be utilized in addition to those illustrated, such as other traffic, control, and feedback channels.

[0098] FIG. 5 illustrates an example of a wireless communication network 500 configured to support sidelink communication. In some examples, sidelink communication may include V2X communication. V2X communication involves the wireless exchange of information directly between not only vehicles (e.g., vehicles 502 and 504) themselves, but also directly between vehicles 502 and 504 and infrastructure

(e.g., a roadside unit (RSU) 506), such as streetlights, buildings, traffic cameras, tollbooths or other stationary objects, between vehicles 502 and 504 and pedestrians 508 (e.g., including cyclists, etc.), and between vehicles 502 and 504 and wireless communication networks (e.g., base station 510). In some examples, V2X communication may be implemented in accordance with the New Radio (NR) cellular V2X standard defined by 3GPP, Release 16, or other suitable standard.

[0099] V2X communication enables vehicles 502 and 504 to obtain information related to the weather, nearby accidents, road conditions, activities of nearby vehicles and pedestrians, objects nearby the vehicle, and other pertinent information that may be utilized to improve the vehicle driving experience and increase vehicle safety. In some examples, such V2X data may enable autonomous driving, improve road safety, and improve traffic efficiency. For example, the exchanged V2X data may be utilized by a V2X connected vehicle 502 and 504 to provide in-vehicle collision warnings, road hazard warnings, approaching emergency vehicle warnings, pre-/post-crash warnings and information, emergency brake warnings, traffic jam ahead warnings, lane change warnings, intelligent navigation services, and other similar information. In addition, V2X data received by a V2X connected mobile device of a pedestrian 508 may be utilized to trigger a warning sound, vibration, flashing light, etc., in case of imminent danger.

[0100] The sidelink communication between vehicle-UEs (V-UEs) (e.g., corresponding to the vehicles 502 and 504) or between a V-UE and either an RSU 506 or a pedestrian-UE (P-UE) (e.g., corresponding to the pedestrian 508) may occur over a sidelink 512 utilizing a proximity service (ProSe) PC5 interface. In various aspects of the disclosure, the PC5 interface may further be utilized to support D2D sidelink 512 communication in other proximity use cases. Examples of other proximity use cases may include public safety or commercial (e.g., entertainment, education, office, medical, and/or interactive) based proximity services. In the example shown in FIG. 5, ProSe communication may further occur between UEs 514 and 516.

[0101] ProSe communication may support different operational scenarios, such as in-coverage, out-of-coverage, and partial coverage. Out-of-coverage refers to a scenario in which UEs (e.g., V-UEs corresponding to the vehicles 502 and 504, and P-UEs corresponding to pedestrians 508) are outside of the coverage area of a base station (e.g., base station 510), but each are still configured for ProSe communication. Partial coverage refers to a scenario in which some of the UEs (e.g., a V-UE correspond to the vehicle 504) are outside of the coverage area of the base station 510, while other UEs (e.g., a V-

UE correspond to the vehicle 502, and P-UEs corresponding to pedestrians 508) are in communication with the base station 510. In-coverage refers to a scenario in which UEs (e.g., UEs 514 and 516) are in communication with the base station 510 (e.g., gNB) via a Uu (e.g., cellular interface) connection to receive ProSe service authorization and provisioning information to support ProSe operations.

[0102] To facilitate D2D sidelink communication between, for example, UEs 514 and 516 over the sidelink 512, the UEs 514 and 516 may transmit discovery signals therebetween. In some examples, each discovery signal may include a synchronization signal, such as a primary synchronization signal (PSS) and/or a secondary synchronization signal (SSS) that facilitates device discovery and enables synchronization of communication on the sidelink 512. For example, the discovery signal may be utilized by the UE 516 to measure the signal strength and channel status of a potential sidelink (e.g., sidelink 512) with another UE (e.g., UE 514). The UE 516 may utilize the measurement results to select a UE (e.g., UE 514) for sidelink communication or relay communication.

[0103] In 5G NR sidelink, sidelink communication may utilize transmission or reception resource pools. For example, the minimum resource allocation unit in frequency may be a sub-channel (e.g., which may include, for example, 10, 15, 20, 25, 50, 75, or 100 consecutive resource blocks) and the minimum resource allocation unit in time may be one slot. The number of sub-channels in a resource pool may include between one and twenty-seven sub-channels. A radio resource control (RRC) configuration of the resource pools may be either pre-configured (e.g., a factory setting on the UE determined, for example, by sidelink standards or specifications) or configured by a base station (e.g., base station 510).

[0104] In addition, there may be two main resource allocation modes of operation for sidelink (e.g., PC5) communications. In a first mode, Mode 1, a base station (e.g., gNB) 510 may allocate resources to sidelink devices (e.g., V2X devices or other sidelink devices) for sidelink communication between the sidelink devices in various manners. For example, the base station 510 may allocate sidelink resources dynamically (e.g., a dynamic grant) to sidelink devices, in response to requests for sidelink resources from the sidelink devices. For example, the base station 510 may schedule the sidelink communication via DCI 2_0. In some examples, the base station 510 may schedule the PSCCH/PSSCH within uplink resources indicated in DCI 2_0. The base station 510 may further activate preconfigured sidelink grants (e.g., configured grants) for sidelink

communication among the sidelink devices. In some examples, the base station 510 may activate a configured grant (CG) via RRC signaling. In Mode 1, sidelink feedback may be reported back to the base station 510 by a transmitting sidelink device.

[0105] In a second mode, Mode 2, the sidelink devices may autonomously select sidelink resources for sidelink communication therebetween. In some examples, a transmitting sidelink device may perform resource/channel sensing to select resources (e.g., sub-channels) on the sidelink channel that are unoccupied. Signaling on the sidelink is the same between the two modes. Therefore, from a receiver's point of view, there is no difference between the modes.

[0106] In some examples, sidelink (e.g., PC5) communication may be scheduled by use of sidelink control information (SCI). SCI may include two SCI stages. Stage 1 sidelink control information (first stage SCI) may be referred to herein as SCI-1. Stage 2 sidelink control information (second stage SCI) may be referred to herein as SCI-2.

[0107] SCI-1 may be transmitted on a physical sidelink control channel (PSCCH). SCI-1 may include information for resource allocation of a sidelink resource and for decoding of the second stage of sidelink control information (i.e., SCI-2). SCI-1 may further identify a priority level (e.g., Quality of Service (QoS)) of a PSSCH. For example, ultra-reliable-low-latency communication (URLLC) traffic may have a higher priority than text message traffic (e.g., short message service (SMS) traffic). SCI-1 may also include a physical sidelink shared channel (PSSCH) resource assignment and a resource reservation period (if enabled). Additionally, SCI-1 may include a PSSCH demodulation reference signal (DMRS) pattern (if more than one pattern is configured). The DMRS may be used by a receiver for radio channel estimation for demodulation of the associated physical channel. As indicated, SCI-1 may also include information about the SCI-2, for example, SCI-1 may disclose the format of the SCI-2. Here, the format indicates the resource size of SCI-2 (e.g., a number of REs that are allotted for SCI-2), a number of a PSSCH DMRS port(s), and a modulation and coding scheme (MCS) index. In some examples, SCI-1 may use two bits to indicate the SCI-2 format. Thus, in this example, four different SCI-2 formats may be supported. SCI-1 may include other information that is useful for establishing and decoding a PSSCH resource.

[0108] SCI-2 may be transmitted within the PSSCH and may contain information for decoding the PSSCH. According to some aspects, SCI-2 includes a 16-bit layer 1 (L1) destination identifier (ID), an 8-bit L1 source ID, a hybrid automatic repeat request (HARQ) process ID, a new data indicator (NDI), and a redundancy version (RV). For

unicast communications, SCI-2 may further include a CSI report trigger. For groupcast communications, SCI-2 may further include a zone identifier and a maximum communication range for NACK. SCI-2 may include other information that is useful for establishing and decoding a PSSCH resource.

[0109] In 5G NR technologies and beyond, wireless networks operate with much higher frequency bands such as millimeter wave (mmWave) bands, e.g., FR2 above 28 GHz, FR4 above 60 GHz, or a terahertz (THz) band above 100 GHz, to offer data rates of potentially several tens or hundreds of Gbit/s. Due to the high attenuation and diffraction losses inherent to these bands, any blockage of a line of sight (LoS) path between a transmitter and a receiver may significantly degrade the associated wireless link quality. For example, the received power can drop rapidly and significantly if a LoS path is blocked by moving obstacles such as pedestrians or vehicles. To overcome such rapid variations of the link quality of communication systems operating at higher frequencies (e.g., caused by LoS path blockage), sensing information provided by vehicle onboard sensors (e.g., cameras, radio detection and ranging (RADAR) devices, light detection and ranging (LIDAR) devices, inertia measurement devices, etc.) can be leveraged to provide a vehicle UE, customer UEs within the vehicle, other UEs, and the radio network information regarding the communication environment as well as moving obstacles that could potentially block the LoS path and degrade the communication quality.

[0110] Some wireless communication networks employ so-called perceptive wireless communication where, upon obtaining sensing information from the onboard sensors, a vehicle can employ onboard computation resources and machine learning (ML) models to predict possible blockages or best beam pairs for a vehicle UE or collocated UEs. This prediction information can be sent to a network entity (e.g., a gNB), so that the network entity can proactively initiate beam management or hand-off procedures for the vehicle UE and/or the collocated UE.

[0111] FIG. 6 illustrates an example of a vehicle 602 (which may be referred to as an ego vehicle) that includes a collocated UE 604 (UE 1) and a vehicle UE 606 (UE 2). For example, the vehicle 602 may be equipped with a 5G capable radio transmitter/receiver, and another UE (e.g., a 5G capable mobile device) may be collocated within the vehicle 602 (e.g., a UE used by a driver or a passenger). The collocated UE 604 communicates with the network via one or more communication links 608 (e.g., beamformed links). The vehicle UE 606 communicates with the network via one or more communication links 610 (e.g., beamformed links). The vehicle 602 also includes one or more sensors 612

(e.g., cameras, RADAR devices, LIDAR devices, inertia measurement devices, etc.), each of which can be used to sense objects in a corresponding field-of-view (FoV) 614.

[0112] As illustrated in FIG. 7, when a vehicle 702 (e.g., corresponding to the vehicle 602 of FIG. 6 and/or the vehicles 502 and 504 of FIG. 5) enters into the coverage area of a network entity 704 (e.g., a gNB), there may be static objects (e.g., buildings) as well as moving objects (e.g., cars, trucks, buses, and pedestrians) in the coverage area. As indicated, one or more of the UEs in the vehicle 702 (e.g., UE1 and/or UE2 of FIG. 6) have established communication via a link 706 with the network entity 704 (e.g., via a beam 708 and a beam 710).

[0113] The radio link quality between the network entity 704 and any of the UEs (e.g., UE1 and/or UE2) in the vehicle 702 can be impacted by moving objects and/or stationary objects. For example, a moving vehicle 712 and/or a moving pedestrian 714 can potentially block the LoS link between the network entity 704 and a UE of the vehicle 702.

[0114] Sensing circuitry 716 including one or more sensors 718 is incorporated into the vehicle 712 to sense objects within at least one FoV 720. Using sensing information provided by vehicle sensors, on-board computational resources, and machine learning (ML) inference models 722 deployed at the vehicle 702, the vehicle 702 can predict beam blockages or the best serving beams for the UEs (e.g., UE1 and UE2). This prediction information can be sent to the network entity 704 to initiate beam management for better serving each UE of the vehicle 702 (e.g., UE1 and UE2) .

[0115] FIG. 8 illustrates an example of an on-vehicle ML interference model 802 (e.g., the ML inference model 722 of FIG. 7). Inputs to the ML interference model 802 may include sensing information 804 from a vehicle's sensors. The output of the ML interference model 802 may include a beam blockage prediction 806 in some examples.

[0116] In practice, there may be multiple network entities (e.g., gNBs or RSUs) in the vicinity of a UE (e.g., a vehicle UE). Each of these network entities can potentially become a serving network entity for the UE at some point in time. In some examples, at a given time, only one network entity serves (e.g., provides the Tx beam for) a UE. In many practical use cases, a UE does not have information indicating the exact positions (locations) of the serving network entities. Thus, a UE does not know which of the network entities it has observed using its sensors is currently providing a serving beam. As such, it may be difficult to use preceptive wireless to predict the beam blockage/link quality in these cases.

[0117] The disclosure relates in some aspects to enabling the use of an on-vehicle model (e.g., an ML model) to predict beam blockage by configuring a UE to identify which network entity is the serving network entity. The disclosure relates in some aspects to signaling and procedures for a UE (e.g., a UE in a vehicle) to identify a serving network entity. The disclosure also relates in some aspects to a link status (LoS or non-LoS (NLoS)) determination between a serving network entity and a UE. Here, when sensing information of network entities (e.g., gNBs and RSUs) and surrounding objects are available at a vehicle, the sensing information may be used to assist the communication between the network and any UEs associated with the vehicle. For example, the communication assist feature may be triggered when the serving network entity is in the field-of-view of the UE (e.g., a UE in a vehicle).

[0118] In some examples, a UE can determine whether the link between itself and the serving network entity is LoS or NLoS (e.g., based, in part, on a DL channel impulse response (CIR)). If the link between a UE and a serving network entity is NLoS, then the sensing assist communication feature is not enabled. On the other hand, if the link between the UE and the serving network entity is LoS, then sensing information can potentially be used to assist communication (e.g., provide a transmit (Tx) or receive (Rx) beam recommendation or restriction reference). In some examples, a neural network in the UE may be used to determine the LoS or NLoS status.

[0119] FIG. 9 illustrates an example of various angles between a vehicle 902 (e.g., the vehicle 702 of FIG. 7, the vehicle 602 of FIG. 6, etc.), a first network entity 904 (e.g., a gNB or RSU), a second network entity 906 (e.g., a gNB or RSU), and a third network entity 908 (e.g., a gNB or RSU). One or more of the UEs (e.g., UE1 and/or UE2 of FIG. 6) in the vehicle 902 may establish communication via various links with one of more of the first network entity 904, the second network entity 906, and the third network entity 908. FIG. 9 illustrates a link 910 (e.g., a LoS link) between a UE of the vehicle 902 and the first network entity 904 that is at an angle 912 (θ_A) with respect to a reference line 916 (e.g., the x axis). FIG. 9 also illustrates a link 918 (e.g., a LoS link) between a UE of the vehicle 902 and the second network entity 906 at an angle 920 (θ_B) with respect to the reference line 916. In addition, a link 922 (e.g., a LoS link) between a UE of the vehicle 902 and the third network entity 908 is at an angle 924 (θ_C) with respect to the reference line 916.

[0120] The communication via the link 910 is conducted via a beam 926 and a beam 928. The beam 926 has an angle of departure (AoD) 930 with respect to the orientation of

reference line 916. The beam 928 has an angle of arrival (AoA) 932 with respect to the reference line 916. In some examples, the beams 926 and 928 may be aligned with the line of the link 910.In some examples, the beams 926 and 928 may be misaligned (e.g., slightly misaligned) with the line of the link 910 (e.g., as depicted in FIG. 9).

[0121] The disclosure relates in some aspects to using measurements (e.g., AoA measurements, etc.) to identify a serving network entity. Here, using sensing information provided by camera, a LIDAR device, a RADAR device, an inertia measurement unit (IMU), etc., a UE (e.g., in a vehicle) can estimate the orientations (in the vehicle coordinates) of all the network entities (e.g., RSUs and/or gNBs) that have been observed. For example, the UE can estimate θ_A, θ_B, and θ_C described above in conjunction with FIG. 9.

[0122] The UE can also obtain the angle-of-departure (AoD) and angle-of-arrival (AoA) information of each transmit (Tx) beam and each receive (Rx) beam (e.g., corresponding to AoD and AoA in FIG. 9). This information can be derived, for example, from DL measurements (e.g., CSI-RS measurements, DL CIR, etc.). Using both sensing geometry information as well as DL (e.g., DL RS) measurements, the UE can corroborate this angle and orientation information and thereby identify the serving network entity (e.g., the first network entity 904 in FIG. 9).

[0123] Some wireless communication systems employ a positioning server to enable UE positioning through the use of positioning reference signals (PRSs). Here, the location server configures multiple base stations to transmit PRSs. This enables a UE to measure the PRSs and feedback corresponding measurement information to the location server. The location server may then generate a location estimate for the UE (e.g., using triangulation or some other suitable technique).

[0124] The disclosure relates in some aspects to using a configured positioning reference signal (PRS) from neighbor cells for AoA and/or AoD determination. For example, a network entity (e.g., a gNB) may configure a PRS of a current cell and additional neighbor cells. That is, the transmission of PRS signals can be triggered and coordinated by the network entity (e.g., a serving gNB) rather than a location server.

[0125] In contrast with the traditional PRS configuration discussed above, these neighbor cells may be geographically close to the configuring network entity (e.g., serving gNB). Also, the number of configured PRSs for estimating UE location may be less than or equal to 3 in some examples (in contrast with the traditional PRS configuration that may use a

larger number of PRSs). By measuring PRS from a serving cell as well as nearby neighbor cells, a UE can determine AoA more accurately.

[0126] The disclosure relates in some aspects to neural network (NN) enabled sensing and identification. In this case, an NN can be used to generate beam information, in contrast with the procedure described above that involves identifying a serving network entity (e.g., a gNB or RSU) based on AoA and AoD measurements and using this information to assist communication.

[0127] FIG. 10 illustrates an example of such a neural network 1002. As indicated, the inputs 1004 to the neural network 1002 may include sensing information (e.g., image information), DL information (e.g., DL CIR), and/or other information representative of the current network. The outputs 1006 of the neural network 1002 may include recommended Tx/Rx beams, restricted Tx/Rx beams, and/or other beam information.

[0128] The disclosure relates in some aspects to an NN that is trained on the network entity (e.g., gNB) side and inferenced (e.g., used) on the UE side. Here, since the network entity is fixed in location and can collect information regarding its surrounding environment (e.g., based on received signaling), it may be more efficient and accurate to train the NN on the network entity side rather than the UE side.

[0129] It may be more efficient to inference the NN on the UE side, however, since the UE can directly feed sensing image and DL information (e.g., DL CIR) representative of the current network to the NN. Here, the UE does not need to send sensing image to the network entity (which may consume significant bandwidth). In addition, as compared to the approach discussed above, the UE does not need to measure reference signals (e.g., PRS) or calculate AoAs to identify the location of the network entity, thereby reducing the processing requirements of the UE. Instead, using an NN trained in the network entity with transmitted information, and using sensing and DL (e.g., DL CIR) input from the UE side, the NN can directly generate the required output to assist communication.

[0130] Thus, when the sensing assisted communication feature is enabled (e.g., link status is determined as LoS as discussed above), the UE can request the network entity to download the NN. The network entity may then transmit information about the NN and the required configuration to UE (e.g., via a DL MAC-CE or RRC signaling). Once the UE obtains the NN model, the UE can feed the sensing information and/or the DL information (e.g., DL CIR) into the NN, so that an expected output can be derived such as a recommended Tx/Rx beam, a restricted Tx/Rx beam, etc.

[0131] FIG. 11 is a signaling diagram 1100 illustrating an example of signaling associated with the exchange of path information in a wireless communication system including a first network entity 1102 (e.g., a base station), a user equipment 1104, and at least one other network entity 1106. In some examples, the first network entity 1102 and the at least one other network entity 1106 may correspond to any of the network entities, base stations, CUs, DU, RUs, or scheduling entities shown in any of FIGs. 1 - 3, 5, 7, 9, 12, and 16. In some examples, the user equipment 1104 may correspond to any of the UEs or scheduled entities shown in any of FIGs. 1 - 3, 5, 6, 7, 9, 12, and 13.

[0132] At # 1108 of FIG. 11, the first network entity 1102 and the at least one other network entity 1106 may coordinate the transmission of RF signaling. For example, the first network entity 1102 may request that the at least one other network entity 1106 transmit positioning reference signals. In some aspects, these positioning reference signals may be different from (e.g., based on a different sequence than) positioning reference signals that are configured by a positioning server.

[0133] At # 1110, the first network entity 1102 transmits RF signals. In some examples, these RF signals may be reference signals (e.g., CSI-RSs). In some examples, these RF signal may be directed to the user equipment 1104.

[0134] At # 1112, the at least one other network entity 1106 transmits RF signals. In some examples, these RF signals may be reference signals (e.g., CSI-RSs). In some examples, these RF signal may be directed to the user equipment 1104.

[0135] At # 1114, the user equipment 1104 senses objects in its FoV. For example, based on imaging signals received from image sensors associated with (e.g., connected to) the user equipment 1104, the user equipment 1104 may identify the types of objects in the FoV (e.g., based on the shapes of the objects), the location of each object, and any movement of each object.

[0136] At # 1116, the user equipment 1104 identifies one of the sensed objects (e.g., designated as a first sensed object) as the current serving network entity for the user equipment 1104 (e.g., the first network entity 1102). For example, by comparing the angle to the object as determined from the sensed image information to the angle to the serving network entity as determined based on received RF signals (e.g., based on the particular beam used by the user equipment 1104 to receive a reference signal and/or the particular beam used by the serving network entity to transmit a reference signal), the user equipment 1104 can determine that a particular sensed object is the serving network

entity. Thus, the user equipment 1104 may determine the LoS to the first network entity 1102 within the FoV.

[0137] At # 1118, the user equipment 1104 generates path information based on sensed and received signals. In some examples, the generation of the path information may involve predicting beam blockages in the FoV. For example, the user equipment 1104 may determine that an object (e.g., a vehicle) is moving toward the LoS between the user equipment 1104 and the first network entity 1102. In some examples, the user equipment 1104 may determine that for a certain period of time in the future (e.g., based on the path and velocity of the object), the object will block one or more of the candidate beams that the first network entity 1102 and the user equipment 1104 may use to communicate. In this case, the user equipment 1104 may generate a list of beams that are predicted to be blocked and/or a list of beams that are predicted to not be blocked during that period of time. The user equipment 1104 may generate others lists of beams for other time periods in a similar manner.

[0138] At # 1120, the user equipment 1104 sends the path information to the first network entity 1102. For example, the user equipment 1104 may send a MAC-CE or an RRC message that includes the path information to the first network entity 1102.

[0139] At # 1122, the first network entity 1102 selects at least one beam for communication between the first network entity 1102 and the user equipment 1104 based on the path information received at # 1120. For example, for a communication that is to be scheduled during a specific period of time (e.g., during a specific time slot), the first network entity 1102 may select at least one beam that is predicted to not be blocked during that period of time.

[0140] At # 1124, the first network entity 1102 schedules a communication between the first network entity 1102 and the user equipment 1104 using the beam(s) selected at # 1122. In some examples, the communication may be a downlink communication. In some examples, the communication may be an uplink communication.

[0141] At # 1126, the first network entity 1102 sends a DCI based on the scheduling of # 1124 to the user equipment 1104. In some examples, this DCI include transmission configuration indication (TCI) information that indicates one or more beams to be used for the communication. At # 1128, the first network entity 1102 and the user equipment 1104 conduct the communication scheduled by the DCI using the designated beams.

[0142] FIG. 12 is a signaling diagram 1200 illustrating another example of signaling associated with the exchange of beam information in a wireless communication system

including a first network entity 1202 (e.g., a base station), a user equipment 1204, and at least one other network entity 1206. In some examples, the first network entity 1202 and the at least one other network entity 1206 may correspond to any of the network entities, base stations, CUs, DU, RUs, or scheduling entities shown in any of FIGs. 1 - 3, 5, 7, 9, 11, and 16. In some examples, the user equipment 1204 may correspond to any of the UEs or scheduled entities shown in any of FIGs. 1 - 3, 5, 6, 7, 9, 11, and 13.

[0143] At # 1208 of FIG. 12, the first network entity 1202 and the at least one other network entity 1206 may coordinate the transmission of RF signaling. For example, the first network entity 1202 may request that the at least one other network entity 1206 transmit positioning reference signals. In some aspects, these positioning reference signals may be different from (e.g., based on a different sequence than) positioning reference signals that are configured by a positioning server.

[0144] At # 1210, the first network entity 1202 transmits RF signals. In some examples, these RF signals may be reference signals (e.g., CSI-RSs). In some examples, these RF signal may be directed to the user equipment 1204.

[0145] At # 1212, the at least one other network entity 1206 transmits RF signals. In some examples, these RF signals may be reference signals (e.g., CSI-RSs). In some examples, these RF signal may be directed to the user equipment 1204.

[0146] At # 1214, the user equipment 1204 senses objects in its FoV. For example, based on imaging signals received from image sensors associated with (e.g., connected to) the user equipment 1204, the user equipment 1204 may identify the types of objects in the FoV (e.g., based on the shapes of the objects), the location of each object, and any movement of each object.

[0147] At # 1216, the user equipment 1204 transmits information based on the RF signals received at # 1210 and/or # 1212 and based on the sensing information generated at # 1214 to the first network entity 1202 so that the first network entity 1202 can train a neural network. In practice, the user equipment 1204 may repeatedly acquire RF signals and sensing information and send corresponding information to the first network entity 1202 for the neural network training.

[0148] At # 1218, the first network entity 1202 trains a neural network based on the information received at # 1216. Here, since neural network training may involve significant resources (e.g., processing power), the neural network training is advantageously offloaded from the user equipment 1204, thereby conserving the resources of the user equipment 1204.

[0149] At optional # 1220, the user equipment 1204 may send a message to the first network entity 1202, where the message requests the first network entity 1202 to send to the user equipment 1204 information (e.g., parameters) that define the neural network. In this way, the user equipment 1204 may acquire a current version of the neural network as trained by the first network entity 1202.

[0150] At # 1222, the first network entity 1202 sends the neural network information to the user equipment 1204. In some examples, this information may include the weights of the various layers of the neural network.

[0151] At # 1224, the first network entity 1202 continues to transmit RF signals. In some examples, these RF signals may be reference signals (e.g., CSI-RSs). In some examples, these RF signal may be directed to the user equipment 1204.

[0152] At # 1226, the at least one other network entity 1206 continues to transmit RF signals. In some examples, these RF signals may be reference signals (e.g., CSI-RSs). In some examples, these RF signal may be directed to the user equipment 1204.

[0153] At # 1228, the user equipment 1204 continues to sense objects in its FoV. For example, based on imaging signals received from image sensors associated with (e.g., connected to) the user equipment 1204, the user equipment 1204 may identify the types of objects in the FoV (e.g., based on the shapes of the objects), the location of each object, and any movement of each object.

[0154] At # 1230, the user equipment 1204 uses the neural network to generate beam information that is indicative of any beam blockages that are predicted to occur between the user equipment 1204 and the first network entity 1202 during a period of time. In this case, the inputs to the neural network may be information based on the RF signals received at # 1224 and/or # 1226 and based on the sensing information generated at # 1228.

[0155] In some examples, the neural network may generate a list of beams that are predicted to be blocked and/or a list of beams that are predicted to not be blocked during the period of time. The neural network may generate others lists of beams for other time periods in a similar manner.

[0156] At # 1232, the user equipment 1204 sends the beam information to the first network entity 1202. For example, the user equipment 1204 may send a MAC-CE or an RRC message that includes the beam information to the first network entity 1202. The first network entity 1202 and the user equipment 1204 may then perform operations similar to the operations described above at # 1122 through # 1124 of FIG. 11. For

example, the first network entity 1202 may select at least one beam for communication between the first network entity 1202 and the user equipment 1204 based on the beam information received at # 1232. The first network entity 1202 may schedule a communication between the first network entity 1202 and the user equipment 1204 using the selected beam(s). The first network entity 1202 may send a DCI based on this scheduling to the user equipment 1204, and the first network entity 1202 and the user equipment 1204 may conduct the communication scheduled by the DCI using the designated beams.

[0157] FIG. 13 is a block diagram illustrating an example of a hardware implementation for a user equipment 1300 employing a processing system 1314. For example, the user equipment 1300 may be a device configured to wirelessly communicate with a network entity, as discussed in any one or more of FIGs. 1 - 12. In some implementations, the user equipment 1300 may correspond to any of the UEs or scheduled entities shown in any of FIGs. 1 - 3, 5 - 7, 9, and 11 - 12.

[0158] In accordance with various aspects of the disclosure, an element, or any portion of an element, or any combination of elements may be implemented with the processing system 1314. The processing system 1314 may include one or more processors 1304. Examples of processors 1304 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. In various examples, the user equipment 1300 may be configured to perform any one or more of the functions described herein. That is, the processor 1304, as utilized in a user equipment 1300, may be used to implement any one or more of the processes and procedures described herein.

[0159] The processor 1304 may in some instances be implemented via a baseband or modem chip and in other implementations, the processor 1304 may include a number of devices distinct and different from a baseband or modem chip (e.g., in such scenarios as may work in concert to achieve the examples discussed herein). And as mentioned above, various hardware arrangements and components outside of a baseband modem processor can be used in implementations, including RF-chains, power amplifiers, modulators, buffers, interleavers, adders/summers, etc.

[0160] In this example, the processing system 1314 may be implemented with a bus architecture, represented generally by the bus 1302. The bus 1302 may include any

number of interconnecting buses and bridges depending on the specific application of the processing system 1314 and the overall design constraints. The bus 1302 communicatively couples together various circuits including one or more processors (represented generally by the processor 1304), a memory 1305, and computer-readable media (represented generally by the computer-readable medium 1306). The bus 1302 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further. A bus interface 1308 provides an interface between the bus 1302, a transceiver 1310 and an antenna array 1320 and between the bus 1302 and an interface 1330. The transceiver 1310 provides a communication interface or means for communicating with various other apparatuses over a wireless transmission medium. The interface 1330 provides a communication interface or means of communicating with various other apparatuses and devices (e.g., other devices housed within the same apparatus as the scheduled entity or other external apparatuses) over an internal bus or external transmission medium, such as an Ethernet cable. Depending upon the nature of the user equipment 1300, the interface 1330 may include a user interface (e.g., keypad, display, speaker, microphone, joystick). Of course, such a user interface is optional, and may be omitted in some examples, such as an IoT device.

[0161] The processor 1304 is responsible for managing the bus 1302 and general processing, including the execution of software stored on the computer-readable medium 1306. The software, when executed by the processor 1304, causes the processing system 1314 to perform the various functions described below for any particular apparatus. The computer-readable medium 1306 and the memory 1305 may also be used for storing data that is manipulated by the processor 1304 when executing software. For example, the memory 1305 may store path information 1315 (e.g., beam information) used by the processor 1304 for the antenna port-related operations described herein.

[0162] One or more processors 1304 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. The software may reside on a computer-readable medium 1306.

[0163] The computer-readable medium 1306 may be a non-transitory computer-readable medium. A non-transitory computer-readable medium includes, by way of example, a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., a compact disc (CD) or a digital versatile disc (DVD)), a smart card, a flash memory device (e.g., a card, a stick, or a key drive), a random access memory (RAM), a read only memory (ROM), a programmable ROM (PROM), an erasable PROM (EPROM), an electrically erasable PROM (EEPROM), a register, a removable disk, and any other suitable medium for storing software and/or instructions that may be accessed and read by a computer. The computer-readable medium 1306 may reside in the processing system 1314, external to the processing system 1314, or distributed across multiple entities including the processing system 1314. The computer-readable medium 1306 may be embodied in a computer program product. By way of example, a computer program product may include a computer-readable medium in packaging materials. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

[0164] The user equipment 1300 may be configured to perform any one or more of the operations described herein (e.g., as described above in conjunction with FIGs. 1 - 12 and as described below in conjunction with FIGs. 14 - 15). In some aspects of the disclosure, the processor 1304, as utilized in the user equipment 1300, may include circuitry configured for various functions.

[0165] The processor 1304 may include communication and processing circuitry 1341. The communication and processing circuitry 1341 may be configured to communicate with a network entity, such as a gNB. The communication and processing circuitry 1341 may be configured to communicate with a base station and one or more other wireless communication devices over a common carrier shared between a cellular (e.g., Uu) interface and a sidelink (e.g., PC5) interface. The communication and processing circuitry 1341 may include one or more hardware components that provide the physical structure that performs various processes related to wireless communication (e.g., signal reception and/or signal transmission) as described herein. The communication and processing circuitry 1341 may further include one or more hardware components that provide the physical structure that performs various processes related to signal processing (e.g., processing a received signal and/or processing a signal for transmission) as described herein. In some examples, the communication and processing circuitry 1341 may include

two or more transmit/receive chains (e.g., one chain to communicate with a base station and another chain to communicate with a sidelink device). The communication and processing circuitry 1341 may further be configured to execute communication and processing software 1351 included on the computer-readable medium 1306 to implement one or more functions described herein.

[0166] In some implementations where the communication involves obtaining (e.g., receiving) information, the communication and processing circuitry 1341 may obtain information from a component of the user equipment 1300 (e.g., from the transceiver 1310 that receives the information via radio frequency signaling or some other type of signaling suitable for the applicable communication medium), process (e.g., decode) the information, and output the processed information. For example, the communication and processing circuitry 1341 may output the information to another component of the processor 1304, to the memory 1305, or to the bus interface 1308. In some examples, the communication and processing circuitry 1341 may receive one or more of signals, messages, other information, or any combination thereof. In some examples, the communication and processing circuitry 1341 may receive information via one or more channels. In some examples, the communication and processing circuitry 1341 may receive one or more of signals, messages, SCIs, feedback, other information, or any combination thereof. In some examples, the communication and processing circuitry 1341 may receive information via one or more of a PSCCH, a PSSCH, a PSFCH, some other type of channel, or any combination thereof. In some examples, the communication and processing circuitry 1341 may include functionality for a means for obtaining (e.g., obtaining indications, signals, etc., from another apparatus). In some examples, the communication and processing circuitry 1341 and/or the transceiver 1310 may include functionality for a means for receiving (e.g., receiving indications, data, or other information from another apparatus). In some examples, the communication and processing circuitry 1341 may include functionality for a means for decoding.

[0167] In some implementations where the communication involves outputting (e.g., transmitting) information, the communication and processing circuitry 1341 may obtain information (e.g., from another component of the processor 1304, the memory 1305, or the bus interface 1308), process (e.g., encode) the information, and output the processed information. For example, the communication and processing circuitry 1341 may output the information to the transceiver 1310 (e.g., that transmits the information via radio frequency signaling or some other type of signaling suitable for the applicable

communication medium). In some examples, the communication and processing circuitry 1341 may send one or more of signals, messages, other information, or any combination thereof. In some examples, the communication and processing circuitry 1341 may send information via one or more channels. In some examples, the communication and processing circuitry 1341 may send one or more of signals, messages, SCIs, feedback, other information, or any combination thereof. In some examples, the communication and processing circuitry 1341 may send information via one or more of a PSCCH, a PSSCH, a PSFCH, some other type of channel, or any combination thereof. In some examples, the communication and processing circuitry 1341 may include functionality for a means for outputting (e.g., outputting indications or other information to another apparatus). In some examples, the communication and processing circuitry 1341 may include functionality for a means for sending (e.g., sending indications or other information to another entity). In some examples, the communication and processing circuitry 1341 and/or the transceiver 1310 may include functionality for a means for transmitting (e.g., transmitting an indication, a request, data, or other information to another apparatus). In some examples, the communication and processing circuitry 1341 may include functionality for a means for encoding.

[0168] The processor 1304 may include positioning processing circuitry 1342 configured to perform positioning processing-related operations as discussed herein (e.g., one or more of the operations described above in conjunction with FIGs. 6 - 12). The positioning processing circuitry 1342 may be configured to execute positioning processing software 1352 included on the computer-readable medium 1306 to implement one or more functions described herein.

[0169] The positioning processing circuitry 1342 may include functionality for a means for receiving (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the positioning processing circuitry 1342 may cooperate with the communication and processing circuitry 1341 and/or the transceiver 1310 to receive reference signals transmitted by one or more gNBs, and process the received signals to determine a received power level (e.g., RSRP) or a CIR for each signal. As another example, the positioning processing circuitry 1342 may cooperate with the communication and processing circuitry 1341 and/or the transceiver 1310 to receive a message from a network entity (e.g., via a MAC-CE or RRC signaling), where the message indicates that the user equipment 1300 is to measure positioning reference signals transmitted by one or more gNBs.

[0170] The positioning processing circuitry 1342 may include functionality for a means for sensing an object (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the positioning processing circuitry 1342 may obtain signals from one or more sensors (e.g., a digital camera, a LIDAR device, a RADAR device, etc.) and process the signals to identify objects within a corresponding FoV.

[0171] The positioning processing circuitry 1342 may include functionality for a means for identifying a position of an object (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the positioning processing circuitry 1342 may obtain signals from one or more sensors (e.g., a digital camera, a LIDAR device, a RADAR device, etc.) and process the signals to identify a correspondence between a sensed object within a FoV and an object that transmits RF signals.

[0172] The positioning processing circuitry 1342 may include functionality for a means for determining whether an object is within a LoS of the user equipment 1300 (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the positioning processing circuitry 1342 may obtain signals from one or more sensors (e.g., a digital camera, a LIDAR device, a RADAR device, etc.) and process the signals to identify a correspondence between a sensed object within a FoV and an object that transmits RF signals. The positioning processing circuitry 1342 may then determine whether there are any other objects blocking the LoS between the user equipment 1300 and the sensed object.

[0173] The processor 1304 may include path information processing circuitry 1343 configured to perform path information processing-related operations as discussed herein (e.g., one or more of the operations described above in conjunction with FIGs. 6 - 12). The path information processing circuitry 1343 may be configured to execute path information processing software 1353 included on the computer-readable medium 1306 to implement one or more functions described herein.

[0174] The path information processing circuitry 1343 may include functionality for a means for transmitting path information (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1343 may cooperate with the communication and processing circuitry 1341 and the transceiver 1310 to transmit a message including path information to a network entity (e.g., via a MAC-CE or RRC signaling).

[0175] The path information processing circuitry 1343 may include functionality for a means for generating path information (e.g., as described above in conjunction with FIGs.

6 - 12). For example, the path information processing circuitry 1343 may determine based on the predicted positions of various objects within a FoV, whether one or more of the objects may block a beam associated with a network entity and a UE (e.g., within or near a LoS between the network entity and the UE). The path information processing circuitry 1343 may then generate path information that identifies the beams that are predicted to be blocked and/or the beams that are predicted to not be blocked. As another example, the path information processing circuitry 1343 may include a neural network that predicts whether one or more of objects may block a beam associated with a network entity and a UE. The path information processing circuitry 1343 may thereby generate beam information that identifies the beams that are predicted to be blocked and/or the beams that are predicted to not be blocked.

[0176] The path information processing circuitry 1343 may include functionality for a means for transmitting (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1343 may cooperate with the communication and processing circuitry 1341 and/or the transceiver 1310 to receive reference signals transmitted by one or more gNBs and obtain signals from at least one image sensors. The path information processing circuitry 1343 may then cooperate with the communication and processing circuitry 1341 and/or the transceiver 1310 to transmit information based on the reference signals and the image sensor signals to a network entity (e.g., via a MAC-CE or RRC signaling) for neural network training. As another example, the path information processing circuitry 1343 may cooperate with the communication and processing circuitry 1341 and/or the transceiver 1310 to transmit a request for neural network information to a network entity (e.g., via a MAC-CE or RRC signaling).

[0177] The path information processing circuitry 1343 may include functionality for a means for receiving (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1343 may cooperate with the communication and processing circuitry 1341 and/or the transceiver 1310 to receive a message transmitted by a network entity (e.g., via a MAC-CE or RRC signaling), and parse the message to extract neural network information.

[0178] FIG. 14 is a flow chart illustrating an example method 1400 for wireless communication in accordance with some aspects of the present disclosure. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be

required for implementation of all examples. In some examples, the method 1400 (e.g., a method for wireless communication at a user equipment) may be carried out by the user equipment 1300 illustrated in FIG. 13. In some examples, the method 1400 may be carried out by any suitable apparatus or means for carrying out the functions or algorithm described below.

[0179] At block 1402, a user equipment may receive a first reference signal from a first network entity. In some examples, the positioning processing circuitry 1342 together with the communication and processing circuitry 1341 and the transceiver 1310, shown and described in FIG. 13, may provide a means to receive a first reference signal from a first network entity.

[0180] At block 1404, the user equipment may sense at least one first object to provide a first sensing signal. In some examples, the positioning processing circuitry 1342, shown and described in FIG. 13, may provide a means to sense at least one first object to provide a first sensing signal.

[0181] At block 1406, the user equipment may transmit path information to the first network entity, the path information being based on the first reference signal and the first sensing signal. In some examples, the path information processing circuitry 1343 together with the communication and processing circuitry 1341 and the transceiver 1310, shown and described in FIG. 13, may provide a means to transmit path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

[0182] In some examples, the path information may include beam information for at least one beam between the user equipment and the first network entity. In some examples, the path information may include pathloss information for at least one signal path between the user equipment and the first network entity.

[0183] In some examples, the path information indicates at least one recommended beam for communication between the first network entity and the user equipment. In some examples, the path information indicates a predicted beam blockage associated with communication between the first network entity and the user equipment. In some examples, the path information indicates a restricted beam.

[0184] In some examples, the first sensing signal may include compressed sensing information of perceived objects. In some examples, the first sensing signal may include at least one of a signal generated by a camera, a light detection and ranging (LIDAR) signal, or a radio detection and ranging (RADAR) signal. In some examples, the first

reference signal may include at least one of a channel state information - reference signal (CSI-RS) or a positioning reference signal (PRS).

[0185] In some examples, the user equipment may identify a position of the first network entity based on the first reference signal and the first sensing signal. In some examples, the user equipment may generate the path information based on the position of the first network entity.

[0186] In some examples, generating the path information may include identifying a first object that is at least partially blocking a first beam associated with the first network entity and the user equipment. In some examples, generating the path information may include identifying a second object that is predicted to at least partially block a second beam associated with the first network entity and the user equipment at a future point in time.

[0187] In some examples, identifying the position of the first network entity may include calculating a first angle to a first object of the at least one first object based on the first sensing signal, calculating a second angle to the first network entity based on the first reference signal, and identifying the first object as the first network entity based on the first angle and the second angle.

[0188] In some examples, the user equipment may determine, based on the first reference signal and the first sensing signal, that the first network entity is within a line of sight of the user equipment. In some examples, the user equipment may generate the path information based on the determining that the first network entity is within the line of sight of the user equipment.

[0189] In some examples, the user equipment may receive a message from the first network entity, the message indicating that user equipment is to measure first positioning reference signals transmitted by the first network entity and at least one other network entity. In some examples, the first reference signal may include one of the first positioning reference signals. In some examples, the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

[0190] In some examples, the path information is generated by a neural network. In some examples, the user equipment may receive at least one second reference signal from at least one other network entity, sense at least one second object to provide a second sensing signal, and transmit information based on the at least one second reference signal and the second sensing signal to the first network entity for neural network training.

[0191] In some examples, the user equipment may transmit a request to the first network entity for neural network information. In some examples, the user equipment may receive

the neural network information from the first network entity, and generate the path information based on the neural network information, the first reference signal, and the first sensing signal. In some examples, the transmitting of the request to the first network entity for the neural network information is triggered based on the first network entity being within a line of sight of the user equipment.

[0192] In some examples, the path information may include the first sensing signal. In some examples, the path information may include downlink channel impulse response information based on the first reference signal.

[0193] FIG. 15 is a flow chart illustrating an example method 1500 for wireless communication in accordance with some aspects of the present disclosure. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all examples. In some examples, the method 1500 (e.g., a method for wireless communication at a user equipment) may be carried out by the user equipment 1300 illustrated in FIG. 13. In some examples, the method 1500 may be carried out by any suitable apparatus or means for carrying out the functions or algorithm described below.

[0194] At block 1502, a user equipment may receive a first reference signal from a first network entity. In some examples, the positioning processing circuitry 1342 together with the communication and processing circuitry 1341 and the transceiver 1310, shown and described in FIG. 13, may provide a means to receive a first reference signal from a first network entity.

[0195] At block 1504, the user equipment may sense at least one first object to provide a first sensing signal. In some examples, the positioning processing circuitry 1342, shown and described in FIG. 13, may provide a means to sense at least one first object to provide a first sensing signal.

[0196] At block 1506, the user equipment may transmit beam information to the first network entity, the beam information being based on the first reference signal and the first sensing signal. In some examples, the path information processing circuitry 1343 together with the communication and processing circuitry 1341 and the transceiver 1310, shown and described in FIG. 13, may provide a means to transmit beam information to the first network entity, the beam information being based on the first reference signal and the first sensing signal.

[0197] In some examples, the beam information indicates at least one recommended beam for communication between the first network entity and the user equipment. In some examples, the beam information indicates a predicted beam blockage associated with communication between the first network entity and the user equipment.

[0198] In some examples, the first sensing signal may include at least one of a signal generated by a camera, a light detection and ranging (LIDAR) signal, or a radio detection and ranging (RADAR) signal. In some examples, the first reference signal may include at least one of a channel state information - reference signal (CSI-RS) or a positioning reference signal (PRS).

[0199] In some examples, the user equipment may identify a position of the first network entity based on the first reference signal and the first sensing signal. In some examples, the user equipment may generate the beam information based on the position of the first network entity.

[0200] In some examples, generating the beam information may include identifying a first object that is at least partially blocking a first beam associated with the first network entity and the user equipment. In some examples, generating the beam information may include identifying a second object that is predicted to at least partially block a second beam associated with the first network entity and the user equipment at a future point in time.

[0201] In some examples, identifying the position of the first network entity may include calculating a first angle to a first object of the at least one first object based on the first sensing signal, calculating a second angle to the first network entity based on the first reference signal, and identifying the first object as the first network entity based on the first angle and the second angle.

[0202] In some examples, the user equipment may determine, based on the first reference signal and the first sensing signal, that the first network entity is within a line of sight of the user equipment. In some examples, the user equipment may generate the beam information based on the determining that the first network entity is within the line of sight of the user equipment.

[0203] In some examples, the user equipment may receive a message from the first network entity, the message indicating that user equipment is to measure first positioning reference signals transmitted by the first network entity and at least one other network entity. In some examples, the first reference signal may include one of the first positioning

reference signals. In some examples, the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

[0204] In some examples, the beam information is generated by a neural network. In some examples, the user equipment may receive at least one second reference signal from at least one other network entity, sense at least one second object to provide a second sensing signal, and transmit information based on the at least one second reference signal and the second sensing signal to the first network entity for neural network training.

[0205] In some examples, the user equipment may transmit a request to the first network entity for neural network information. In some examples, the user equipment may receive the neural network information from the first network entity, and generate the beam information based on the neural network information, the first reference signal, and the first sensing signal. In some examples, the transmitting of the request to the first network entity for the neural network information is triggered based on the first network entity being within a line of sight of the user equipment.

[0206] Referring again to FIG. 13, in one configuration, the user equipment 1300 includes means for receiving a first reference signal from a first network entity, means for sensing at least one first object to provide a first sensing signal, and means for transmitting path information to the first network entity, the path information being based on the first reference signal and the first sensing signal. In one aspect, the aforementioned means may be the processor 1304 shown in FIG. 13 configured to perform the functions recited by the aforementioned means (e.g., as discussed above). In another aspect, the aforementioned means may be a circuit or any apparatus configured to perform the functions recited by the aforementioned means.

[0207] Of course, in the above examples, the circuitry included in the processor 1304 is merely provided as an example, and other means for carrying out the described functions may be included within various aspects of the present disclosure, including but not limited to the instructions stored in the computer-readable medium 1306, or any other suitable apparatus or means described in any one or more of FIGs. 1 – 3 and 5 - 13, and utilizing, for example, the methods and/or algorithms described herein in relation to FIGs. 14 - 15.

[0208] FIG. 16 is a conceptual diagram illustrating an example of a hardware implementation for a network entity 1600 employing a processing system 1614. In some implementations, the network entity 1600 may correspond to any of the network entities, base stations (e.g., gNBs), CUs, DUs, RUs, or scheduling entities shown in any of FIGs. 1- 3, 5, 7, 9, 11, and 12.

[0209] In accordance with various aspects of the disclosure, an element, or any portion of an element, or any combination of elements may be implemented with the processing system 1614. The processing system may include one or more processors 1604. The processing system 1614 may be substantially the same as the processing system 1314 illustrated in FIG. 13, including a bus interface 1608, a bus 1602, memory 1605, a processor 1604, a computer-readable medium 1606, a transceiver 1610, and an antenna array 1620. The memory 1605 may store path information 1615 (e.g., path information) used by the processor 1604 in cooperation with the transceiver 1610 for the antenna port-related operations described herein. Furthermore, the network entity 1600 may include an interface 1630 (e.g., a network interface) that provides a means for communicating with at least one other apparatus within a core network and with at least one radio access network.

[0210] The network entity 1600 may be configured to perform any one or more of the operations described herein (e.g., as described above in conjunction with FIGs. 1 - 12 and as described below in conjunction with FIGs. 17 - 18). In some aspects of the disclosure, the processor 1604, as utilized in the network entity 1600, may include circuitry configured for various functions.

[0211] The processor 1604 may be configured to generate, schedule, and modify a resource assignment or grant of time-frequency resources (e.g., a set of one or more resource elements). For example, the processor 1604 may schedule time–frequency resources within a plurality of time division duplex (TDD) and/or frequency division duplex (FDD) subframes, slots, and/or mini-slots to carry user data traffic and/or control information to and/or from multiple scheduled entities. The processor 1604 may be configured to schedule resources for the transmission of downlink signals. The processor 1604 may further be configured to schedule resources for the transmission of uplink signals.

[0212] In some aspects of the disclosure, the processor 1604 may include communication and processing circuitry 1641. The communication and processing circuitry 1641 may be configured to communicate with a scheduled entity. The communication and processing circuitry 1641 may include one or more hardware components that provide the physical structure that performs various processes related to communication (e.g., signal reception and/or signal transmission) as described herein. The communication and processing circuitry 1641 may further include one or more hardware components that provide the physical structure that performs various processes related to signal processing (e.g.,

processing a received signal and/or processing a signal for transmission) as described herein. The communication and processing circuitry 1641 may further be configured to execute communication and processing software 1651 included on the computer-readable medium 1606 to implement one or more functions described herein.

[0213] The communication and processing circuitry 1641 may further be configured to receive a message from a UE. For example, the message may be included in a MAC-CE carried in a Uu PUSCH or a PSCCH, or included in a Uu RRC message or an SL RRC message, or included in a dedicated Uu PUCCH or PUSCH. The communication and processing circuitry 1641 may further be configured to receive a scheduling request from a UE for an uplink grant or a sidelink grant.

[0214] In some implementations wherein the communication involves obtaining (e.g., receiving) information, the communication and processing circuitry 1641 may obtain information from a component of the network entity 1600 (e.g., from the transceiver 1610 that receives the information via radio frequency signaling or some other type of signaling suitable for the applicable communication medium), process (e.g., decode) the information, and output the processed information. For example, the communication and processing circuitry 1641 may output the information to another component of the processor 1604, to the memory 1605, or to the bus interface 1608. In some examples, the communication and processing circuitry 1641 may receive one or more of signals, messages, other information, or any combination thereof. In some examples, the communication and processing circuitry 1641 may receive information via one or more channels. In some examples, the communication and processing circuitry 1641 may include functionality for a means for obtaining (e.g., obtaining indications, signals, or other information from another apparatus). In some examples, the communication and processing circuitry 1641 and/or the transceiver 1610 may include functionality for a means for receiving (e.g., receiving indications, data, or other information from another apparatus). In some examples, the communication and processing circuitry 1641 may include functionality for a means for decoding.

[0215] In some implementations wherein the communication involves outputting (e.g., transmitting) information, the communication and processing circuitry 1641 may obtain information (e.g., from another component of the processor 1604, the memory 1605, or the bus interface 1608), process (e.g., encode) the information, and output the processed information. For example, the communication and processing circuitry 1641 may output the information to the transceiver 1610 (e.g., that transmits the information via radio

frequency signaling or some other type of signaling suitable for the applicable communication medium). In some examples, the communication and processing circuitry 1641 may send one or more of signals, messages, other information, or any combination thereof. In some examples, the communication and processing circuitry 1641 may send information via one or more channels. In some examples, the communication and processing circuitry 1641 may include functionality for a means for sending (e.g., a means for transmitting). In some examples, the communication and processing circuitry 1641 may include functionality for a means for encoding. In some examples, the communication and processing circuitry 1641 may include functionality for a means for outputting (e.g., outputting indications, signals, or other information to another apparatus). In some examples, the communication and processing circuitry 1641 and/or the transceiver 1610 may include functionality for a means for transmitting (e.g., transmitting data or other information to another apparatus).

[0216] The processor 1604 may include positioning processing circuitry 1642 configured to perform positioning processing-related operations as discussed herein (e.g., one or more of the operations described above in conjunction with FIGs. 6 - 12). The positioning processing circuitry 1642 may be configured to execute positioning processing software 1652 included on the computer-readable medium 1606 to implement one or more functions described herein.

[0217] The positioning processing circuitry 1642 may include functionality for a means for transmitting a message (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the positioning processing circuitry 1642 may generate a message and cooperate with the communication and processing circuitry 1641 and/or the transceiver 1610 to transmit the message (e.g., via an X2 or Xn interface) to one or more gNBs, where the message instructs the gNBs to transmit a positioning reference signal. As another example, the positioning processing circuitry 1642 may generate a message and cooperate with the communication and processing circuitry 1641 and/or the transceiver 1610 to transmit the message (e.g., via a MAC-CE or RRC signaling) to a UE, where the message instructs the UE to monitor for a positioning reference signal from a set of gNBs.

[0218] The processor 1604 may include path information processing circuitry 1643 configured to perform path information processing-related operations as discussed herein (e.g., one or more of the operations described above in conjunction with FIGs. 6 - 12). The path information processing circuitry 1643 may be configured to execute path

information processing software 1653 included on the computer-readable medium 1606 to implement one or more functions described herein.

[0219] The path information processing circuitry 1643 may include functionality for a means for receiving path information (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1643 may cooperate with the communication and processing circuitry 1641 and/or the transceiver 1610 to receive a message from a UE (e.g., via a MAC-CE or RRC signaling), and then parse the message to extract any path information that may be included in the message.

[0220] The path information processing circuitry 1643 may include functionality for a means for selecting a beam for communication (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1643 may identify one or more preferred beams for communication with a UE, where the selection is based on path information received from the UE.

[0221] The path information processing circuitry 1643 may include functionality for a means for receiving information (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1643 may cooperate with the communication and processing circuitry 1641 and/or the transceiver 1610 to receive information from a UE (e.g., via a MAC-CE or RRC signaling), and then parse the message to extract information to be used for neural network training. In some examples, the information is based on positioning signals received by the UE and/or sensing signals generated by the UE (e.g., based on FoV sensing).

[0222] The path information processing circuitry 1643 may include functionality for a means for generating neural network information (e.g., as described above in conjunction with FIGs. 6 - 12). For example, the path information processing circuitry 1643 may use information based on positioning signals received by the UE and/or sensing signals generated by the UE (e.g., based on FoV sensing) as inputs to a neural network, and thereby train the neural network (e.g., by achieving convergence with respect to a target loss function based on a defined ground truth).

[0223] In some examples, the network entity 1600 shown and described above in connection with FIG. 16 may be a disaggregated base station. For example, the network entity 1600 shown in FIG. 16 may include the CU and optionally one or more DUs/RUs of the disaggregated base station. Other DUs/RUs associated with the network entity 1600 may be distributed throughout the network. In some examples, the DUs/RUs may correspond to TRPs associated with the network entity. In some examples, the CU and/or

DU/RU of the disaggregated base station (e.g., within the network entity 1600) may obtain path information from the user equipment and schedule the user equipment based on the path information.

[0224] FIG. 17 is a flow chart illustrating an example method 1700 for wireless communication in accordance with some aspects of the present disclosure. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all examples. In some examples, the method 1700 (e.g., a method for wireless communication at a network entity) may be carried out by the network entity 1600 illustrated in FIG. 16. In some examples, the method 1700 may be carried out by any suitable apparatus or means for carrying out the functions or algorithm described below.

[0225] At block 1702, a first network entity may transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals. In some examples, the positioning processing circuitry 1642 together with the communication and processing circuitry 1641 and the transceiver 1610, shown and described in FIG. 16, may provide a means to transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals.

[0226] At block 1704, a first network entity may transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals. In some examples, the positioning processing circuitry 1642 together with the communication and processing circuitry 1641 and the transceiver 1610, shown and described in FIG. 16, may provide a means to transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals.

[0227] At block 1706, the first network entity may receive path information from the at least one user equipment. In some examples, the path information processing circuitry 1643 together with the communication and processing circuitry 1641 and the transceiver 1610, shown and described in FIG. 16, may provide a means to receive path information from the at least one user equipment.

[0228] In some examples, the path information may include sensing information. In some examples, the path information may include downlink channel impulse response

information based on the first positioning reference signals. In some examples, the network entity may generate beam information based on the sensing information and the downlink channel impulse response information.

[0229] In some examples, the path information may include beam information for at least one beam between the at least one user equipment and the first network entity. In some examples, the path information may include pathloss information for at least one signal path between the at least one user equipment and the first network entity.

[0230] In some examples, the beam information indicates at least one recommended beam for communication between the first network entity and the at least one user equipment. In some examples, the beam information indicates a predicted beam blockage associated with communication between the first network entity and the at least one user equipment.

[0231] In some examples, the beam information is based on at least one of the first positioning reference signals. In some examples, the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

[0232] In some examples, the network entity may select at least one beam for communication with the at least one user equipment based on the path information.

[0233] In some examples, the network entity may receive first information from the at least one user equipment, the first information being based on the first positioning reference signals and a sensing signal. In some examples, the network entity may generate neural network information based on the first information.

[0234] In some examples, the network entity may receive a request from the at least one user equipment for the neural network information. In some examples, the network entity may transmit the neural network information to the at least one user equipment.

[0235] FIG. 18 is a flow chart illustrating an example method 1800 for wireless communication in accordance with some aspects of the present disclosure. As described below, some or all illustrated features may be omitted in a particular implementation within the scope of the present disclosure, and some illustrated features may not be required for implementation of all examples. In some examples, the method 1800 (e.g., a method for wireless communication at a network entity) may be carried out by the network entity 1600 illustrated in FIG. 16. In some examples, the method 1800 may be carried out by any suitable apparatus or means for carrying out the functions or algorithm described below.

[0236] At block 1802, a first network entity may transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals. In some examples, the positioning processing circuitry 1642 together with the communication and processing circuitry 1641 and the transceiver 1610, shown and described in FIG. 16, may provide a means to transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals.

[0237] At block 1804, a first network entity may transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals. In some examples, the positioning processing circuitry 1642 together with the communication and processing circuitry 1641 and the transceiver 1610, shown and described in FIG. 16, may provide a means to transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals.

[0238] At block 1806, the first network entity may receive beam information from the at least one user equipment. In some examples, the path information processing circuitry 1643 together with the communication and processing circuitry 1641 and the transceiver 1610, shown and described in FIG. 16, may provide a means to receive beam information from the at least one user equipment.

[0239] In some examples, the beam information indicates at least one recommended beam for communication between the first network entity and the at least one user equipment. In some examples, the beam information indicates a predicted beam blockage associated with communication between the first network entity and the at least one user equipment.

[0240] In some examples, the beam information is based on at least one of the first positioning reference signals. In some examples, the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

[0241] In some examples, the first network entity may select at least one beam for communication with the at least one user equipment based on the beam information.

[0242] In some examples, the first network entity may receive first information from the at least one user equipment, the first information being based on the first positioning

reference signals and a sensing signal. In some examples, the first network entity may generate neural network information based on the first information.

[0243] In some examples, the first network entity may receive a request from the at least one user equipment for the neural network information. In some examples, the first network entity may transmit the neural network information to the at least one user equipment.

[0244] Referring again to FIG. 16, in one configuration, the network entity 1600 includes means for transmitting at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals, means for transmitting a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals, and means for receiving path information from the at least one user equipment. In one aspect, the aforementioned means may be the processor 1604 shown in FIG. 16 configured to perform the functions recited by the aforementioned means (e.g., as discussed above). In another aspect, the aforementioned means may be a circuit or any apparatus configured to perform the functions recited by the aforementioned means.

[0245] Of course, in the above examples, the circuitry included in the processor 1604 is merely provided as an example, and other means for carrying out the described functions may be included within various aspects of the present disclosure, including but not limited to the instructions stored in the computer-readable medium 1606, or any other suitable apparatus or means described in any one or more of FIGs. 1 - 3, 5 - 12, and 16, and utilizing, for example, the methods and/or algorithms described herein in relation to FIGs. 17 and 18.

[0246] The methods shown in FIGs. 14 - 15 and 17 - 18 may include additional aspects, such as any single aspect or any combination of aspects described below and/or in connection with one or more other processes described elsewhere herein. The following provides an overview of several aspects of the present disclosure.

[0247] Aspect 1: A method for wireless communication at a user equipment, the method comprising: receiving a first reference signal from a first network entity; sensing at least one first object to provide a first sensing signal; and transmitting path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

[0248] Aspect 2: The method of aspect 1, wherein the path information comprises at least one of: beam information for at least one beam between the user equipment and the first network entity; or pathloss information for at least one signal path between the user equipment and the first network entity.

[0249] Aspect 3: The method of aspect 2, wherein the beam information indicates at least one of: a recommended beam for communication between the first network entity and the user equipment; a predicted beam blockage associated with communication between the first network entity and the user equipment; or a restricted beam.

[0250] Aspect 4: The method of any of aspects 1 through 3, wherein the first sensing signal comprises compressed sensing information of perceived objects.

[0251] Aspect 5: The method of any of aspects 1 through 4, wherein the first sensing signal comprises at least one of: a signal generated by a camera; a signal generated by an inertia measurement device; a light detection and ranging (LIDAR) signal; or a radio detection and ranging (RADAR) signal.

[0252] Aspect 6: The method of any of aspects 1 through 5, wherein the first reference signal comprises at least one of: a channel state information - reference signal (CSI-RS); or a positioning reference signal (PRS).

[0253] Aspect 7: The method of any of aspects 1 through 6, further comprising: identifying a position of the first network entity based on the first reference signal and the first sensing signal; and generating the path information based on the position of the first network entity.

[0254] Aspect 8: The method of aspect 7, wherein the generating the path information comprises at least one of: identifying a first object that is at least partially blocking a first beam associated with the first network entity and the user equipment; or identifying a second object that is predicted to at least partially block a second beam associated with the first network entity and the user equipment at a future point in time.

[0255] Aspect 9: The method of any of aspects 7 through 8, wherein the identifying the position of the first network entity comprises: calculating a first angle to a first object of the at least one first object based on the first sensing signal; calculating a second angle to the first network entity based on the first reference signal; and identifying the first object as the first network entity based on the first angle and the second angle.

[0256] Aspect 10: The method of any of aspects 1 through 9, further comprising: determining, based on the first reference signal and the first sensing signal, that the first network entity is within a line of sight of the user equipment; and generating the path

information based on the determining that the first network entity is within the line of sight of the user equipment.

[0257] Aspect 11: The method of any of aspects 1 through 10, further comprising: receiving a message from the first network entity, the message indicating that the user equipment is to measure first positioning reference signals transmitted by the first network entity and at least one other network entity.

[0258] Aspect 12: The method of aspect 11, wherein at least one of: the first reference signal comprises one of the first positioning reference signals; or the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

[0259] Aspect 13: The method of any of aspects 1 through 12, wherein the path information is generated by a neural network.

[0260] Aspect 14: The method of aspect 13, further comprising: receiving at least one second reference signal from at least one other network entity; sensing at least one second object to provide a second sensing signal; and transmitting information based on the at least one second reference signal and the second sensing signal to the first network entity for neural network training.

[0261] Aspect 15: The method of aspect 14, further comprising: transmitting a request to the first network entity for neural network information.

[0262] Aspect 16: The method of aspect 15, further comprising: receiving the neural network information from the first network entity; and generating the path information based on the neural network information, the first reference signal, and the first sensing signal.

[0263] Aspect 17: The method of any of aspects 15 through 16, wherein the transmitting of the request to the first network entity for the neural network information is triggered based on the first network entity being within a line of sight of the user equipment.

[0264] Aspect 18: The method of any of aspects 1 through 17, wherein the path information comprises: the first sensing signal; and downlink channel impulse response information based on the first reference signal.

[0265] Aspect 19: The method of any of aspects 1 through 18, wherein the user equipment comprises a transceiver and a processor.

[0266] Aspect 20: A method for communication at a first network entity, the method comprising: transmitting at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first

positioning reference signals; transmitting a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals; and receiving path information from the at least one user equipment.

[0267] Aspect 21: The method of aspect 20, wherein: the path information comprises sensing information; the path information further comprises downlink channel impulse response information based on the first positioning reference signals; and the method further comprises generating beam information based on the sensing information and the downlink channel impulse response information.

[0268] Aspect 22: The method of aspect 20, wherein the path information comprises at least one of: beam information for at least one beam between the at least one user equipment and the first network entity; or pathloss information for at least one signal path between the at least one user equipment and the first network entity.

[0269] Aspect 23: The method of aspect 22, wherein the beam information indicates at least one recommended beam for communication between the first network entity and the at least one user equipment.

[0270] Aspect 24: The method of any of aspects 22 through 23, wherein the beam information indicates a predicted beam blockage associated with communication between the first network entity and the at least one user equipment.

[0271] Aspect 25: The method of any of aspects 22 through 24, wherein the beam information is based on at least one of the first positioning reference signals.

[0272] Aspect 26: The method of any of aspects 20 through 25, wherein the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

[0273] Aspect 27: The method of any of aspects 20 through 26, further comprising: selecting at least one beam for communication with the at least one user equipment based on the path information.

[0274] Aspect 28: The method of any of aspects 20 through 27, further comprising: receiving first information from the at least one user equipment, the first information being based on the first positioning reference signals and a sensing signal; and generating neural network information based on the first information.

[0275] Aspect 29: The method of aspect 28, further comprising: receiving a request from the at least one user equipment for the neural network information; and transmitting the neural network information to the at least one user equipment.

[0276] Aspect 30: The method of any of aspects 20 through 29, wherein the first network entity comprises a transceiver and a processor.

[0277] Aspect 31: A user equipment comprising: a transceiver, a memory, and a processor coupled to the transceiver and the memory, wherein the processor is configured to perform any of aspects 1 through 19.

[0278] Aspect 32: An apparatus configured for wireless communication comprising at least one means for performing any of aspects 1 through 19.

[0279] Aspect 33: A non-transitory computer-readable medium storing computer-executable code, comprising code for causing an apparatus to perform any of aspects 1 through 19.

[0280] Aspect 34: A first network entity comprising: a transceiver, a memory, and a processor coupled to the transceiver and the memory, wherein the processor is configured to perform any of aspects 20 through 29.

[0281] Aspect 35: An apparatus configured for wireless communication comprising at least one means for performing any of aspects 20 through 29.

[0282] Aspect 36: A non-transitory computer-readable medium storing computer-executable code, comprising code for causing an apparatus to perform any of aspects 20 through 29.

[0283] Several aspects of a wireless communication network have been presented with reference to an example implementation. As those skilled in the art will readily appreciate, various aspects described throughout this disclosure may be extended to other telecommunication systems, network architectures and communication standards.

[0284] By way of example, various aspects may be implemented within other systems defined by 3GPP, such as Long-Term Evolution (LTE), the Evolved Packet System (EPS), the Universal Mobile Telecommunication System (UMTS), and/or the Global System for Mobile (GSM). Various aspects may also be extended to systems defined by the 3rd Generation Partnership Project 2 (3GPP2), such as CDMA2000 and/or Evolution-Data Optimized (EV-DO). Other examples may be implemented within systems employing Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Ultra-Wideband (UWB), Bluetooth, and/or other suitable systems. The actual telecommunication standard, network architecture, and/or communication standard employed will depend on the specific application and the overall design constraints imposed on the system.

[0285] Within the present disclosure, the word "exemplary" is used to mean "serving as an example, instance, or illustration." Any implementation or aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects of the disclosure. Likewise, the term "aspects" does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation. The term "coupled" is used herein to refer to the direct or indirect coupling between two objects. For example, if object A physically touches object B, and object B touches object C, then objects A and C may still be considered coupled to one another—even if they do not directly physically touch each other. For instance, a first object may be coupled to a second object even though the first object is never directly physically in contact with the second object. The terms "circuit" and "circuitry" are used broadly, and intended to include both hardware implementations of electrical devices and conductors that, when connected and configured, enable the performance of the functions described in the present disclosure, without limitation as to the type of electronic circuits, as well as software implementations of information and instructions that, when executed by a processor, enable the performance of the functions described in the present disclosure. As used herein, the term "determining" may include, for example, ascertaining, resolving, selecting, choosing, establishing, calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), and the like. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory), and the like.

[0286] One or more of the components, steps, features and/or functions illustrated in FIGs. 1 - 18 may be rearranged and/or combined into a single component, step, feature or function or embodied in several components, steps, or functions. Additional elements, components, steps, and/or functions may also be added without departing from novel features disclosed herein. The apparatus, devices, and/or components illustrated in FIGs. 1 - 3, 5 - 13, and 16 may be configured to perform one or more of the methods, features, or steps escribed herein. The novel algorithms described herein may also be efficiently implemented in software and/or embedded in hardware.

[0287] It is to be understood that the specific order or hierarchy of steps in the methods disclosed is an illustration of example processes. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the methods may be rearranged. 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 unless specifically recited therein.

[0288] 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 are to be accorded the full scope consistent with the language of the 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. 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 and b; a and c; b and c; and a, b, and c. 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.

CLAIMS

What is claimed is:

1. A method for wireless communication at a user equipment, the method comprising:

receiving a first reference signal from a first network entity;

sensing at least one first object to provide a first sensing signal; and

transmitting path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

2. The method of claim 1, wherein the path information comprises at least one of:

beam information for at least one beam between the user equipment and the first network entity; or

pathloss information for at least one signal path between the user equipment and the first network entity.

3. The method of claim 2, wherein the beam information indicates at least one of:

a recommended beam for communication between the first network entity and the user equipment;

a predicted beam blockage associated with communication between the first network entity and the user equipment; or

a restricted beam.

4. The method of claim 1, wherein the first sensing signal comprises compressed sensing information of perceived objects.

5. The method of claim 1, wherein the first sensing signal comprises at least one of:

a signal generated by a camera;

a signal generated by an inertia measurement device;

a light detection and ranging (LIDAR) signal; or

a radio detection and ranging (RADAR) signal.

6. The method of claim 1, wherein the first reference signal comprises at least one of:

a channel state information - reference signal (CSI-RS); or

a positioning reference signal (PRS).

7. The method of claim 1, further comprising:

identifying a position of the first network entity based on the first reference signal and the first sensing signal; and

generating the path information based on the position of the first network entity.

8. The method of claim 7, wherein the generating the path information comprises at least one of:

identifying a first object that is at least partially blocking a first beam associated with the first network entity and the user equipment; or

identifying a second object that is predicted to at least partially block a second beam associated with the first network entity and the user equipment at a future point in time.

9. The method of claim 7, wherein the identifying the position of the first network entity comprises:

calculating a first angle to a first object of the at least one first object based on the first sensing signal;

calculating a second angle to the first network entity based on the first reference signal; and

identifying the first object as the first network entity based on the first angle and the second angle.

10. The method of claim 1, further comprising:

determining, based on the first reference signal and the first sensing signal, that the first network entity is within a line of sight of the user equipment; and

generating the path information based on the determining that the first network entity is within the line of sight of the user equipment.

11. The method of claim 1, further comprising:

receiving a message from the first network entity, the message indicating that the user equipment is to measure first positioning reference signals transmitted by the first network entity and at least one other network entity.

12. The method of claim 11, wherein at least one of:

the first reference signal comprises one of the first positioning reference signals; or

the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

13. The method of claim 1, wherein the path information is generated by a neural network.

14. The method of claim 13, further comprising:

receiving at least one second reference signal from at least one other network entity;

sensing at least one second object to provide a second sensing signal; and

transmitting information based on the at least one second reference signal and the second sensing signal to the first network entity for neural network training.

15. The method of claim 14, further comprising:

transmitting a request to the first network entity for neural network information.

16. The method of claim 15, further comprising:

receiving the neural network information from the first network entity; and

generating the path information based on the neural network information, the first reference signal, and the first sensing signal.

17. The method of claim 15, wherein the transmitting of the request to the first network entity for the neural network information is triggered based on the first network entity being within a line of sight of the user equipment.

18. The method of claim 1, wherein the path information comprises:

the first sensing signal; and

downlink channel impulse response information based on the first reference signal.

19. A user equipment, comprising:

a transceiver; and

a processor coupled to the transceiver, wherein the processor is configured to:

receive first reference signal from a first network entity;

sense at least one first object to provide a first sensing signal; and

transmit path information to the first network entity, the path information being based on the first reference signal and the first sensing signal.

20. A method for wireless communication at a first network entity, the method comprising:

transmitting at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals;

transmitting a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals; and

receiving path information from the at least one user equipment.

21. The method of claim 20, wherein:

the path information comprises sensing information;

the path information further comprises downlink channel impulse response information based on the first positioning reference signals; and

the method further comprises generating beam information based on the sensing information and the downlink channel impulse response information.

22. The method of claim 20, wherein the path information comprises at least one of:

beam information for at least one beam between the at least one user equipment and the first network entity; or

pathloss information for at least one signal path between the at least one user equipment and the first network entity.

23. The method of claim 22, wherein the beam information indicates at least one recommended beam for communication between the first network entity and the at least one user equipment.

24. The method of claim 22, wherein the beam information indicates a predicted beam blockage associated with communication between the first network entity and the at least one user equipment.

25. The method of claim 22, wherein the beam information is based on at least one of the first positioning reference signals.

26. The method of claim 20, wherein the first positioning reference signals are different from second positioning reference signals associated with a positioning server.

27. The method of claim 20, further comprising:

selecting at least one beam for communication with the at least one user equipment based on the path information.

28. The method of claim 20, further comprising:

receiving first information from the at least one user equipment, the first information being based on the first positioning reference signals and a sensing signal; and

generating neural network information based on the first information.

29. The method of claim 28, further comprising:

receiving a request from the at least one user equipment for the neural network information; and

transmitting the neural network information to the at least one user equipment.

30. A first network entity, comprising:

a transceiver; and

a processor coupled to the transceiver, wherein the processor is configured to:

transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals;

transmit a first message to at least one user equipment , the first message indicating that the at least one user equipment is to measure the first positioning reference signals; and

receive path information from the at least one user equipment.

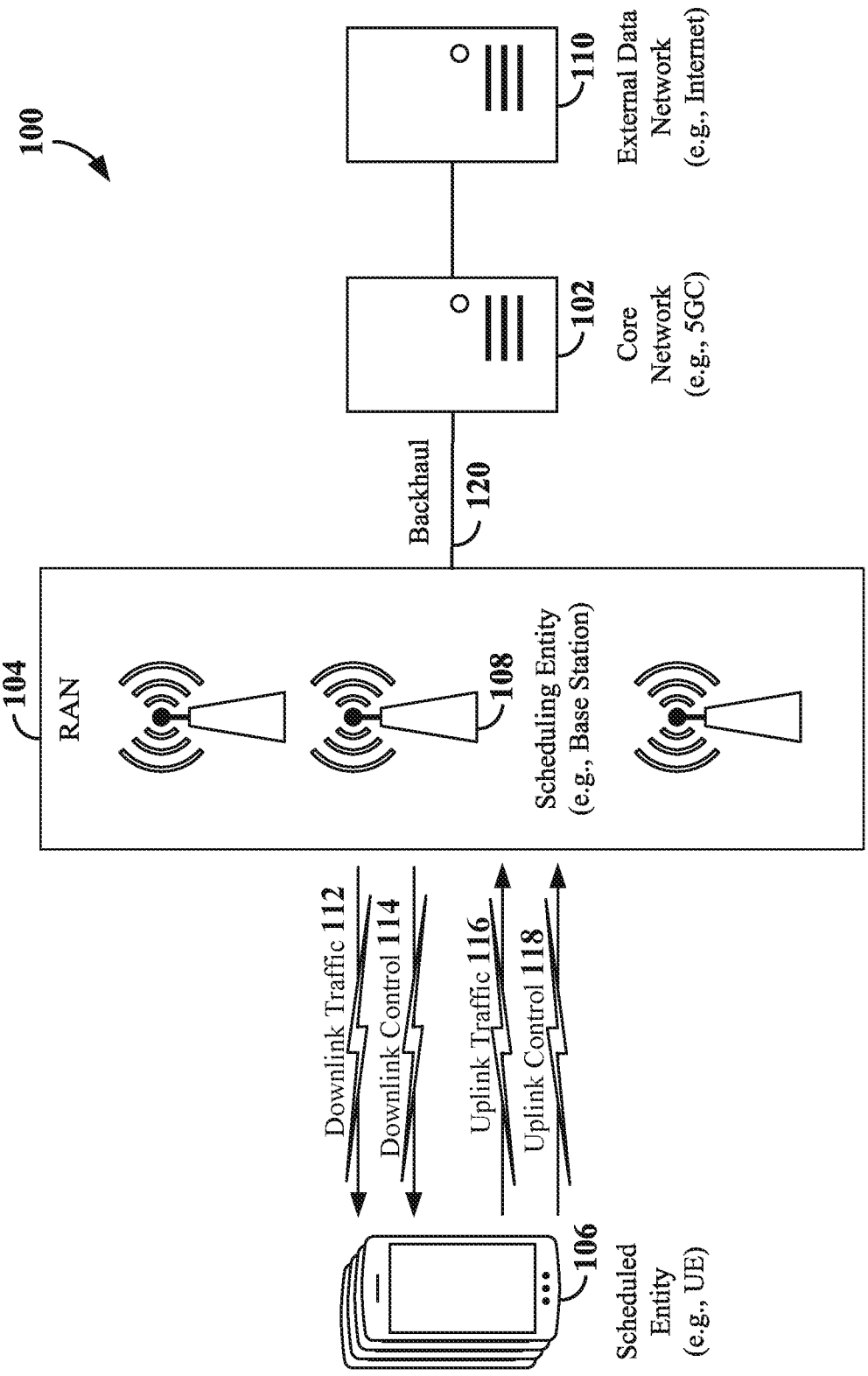

100
104
RAN
108
Scheduling Entity
(e.g., Base Station)
Backhaul
120
102
Core
Network
(e.g., 5GC)
110
External Data
Network
(e.g., Internet)
Downlink Traffic 112
Downlink Control 114
Uplink Traffic 116
Uplink Control 118
106
Scheduled
Entity
(e.g., UE)

FIG. 1

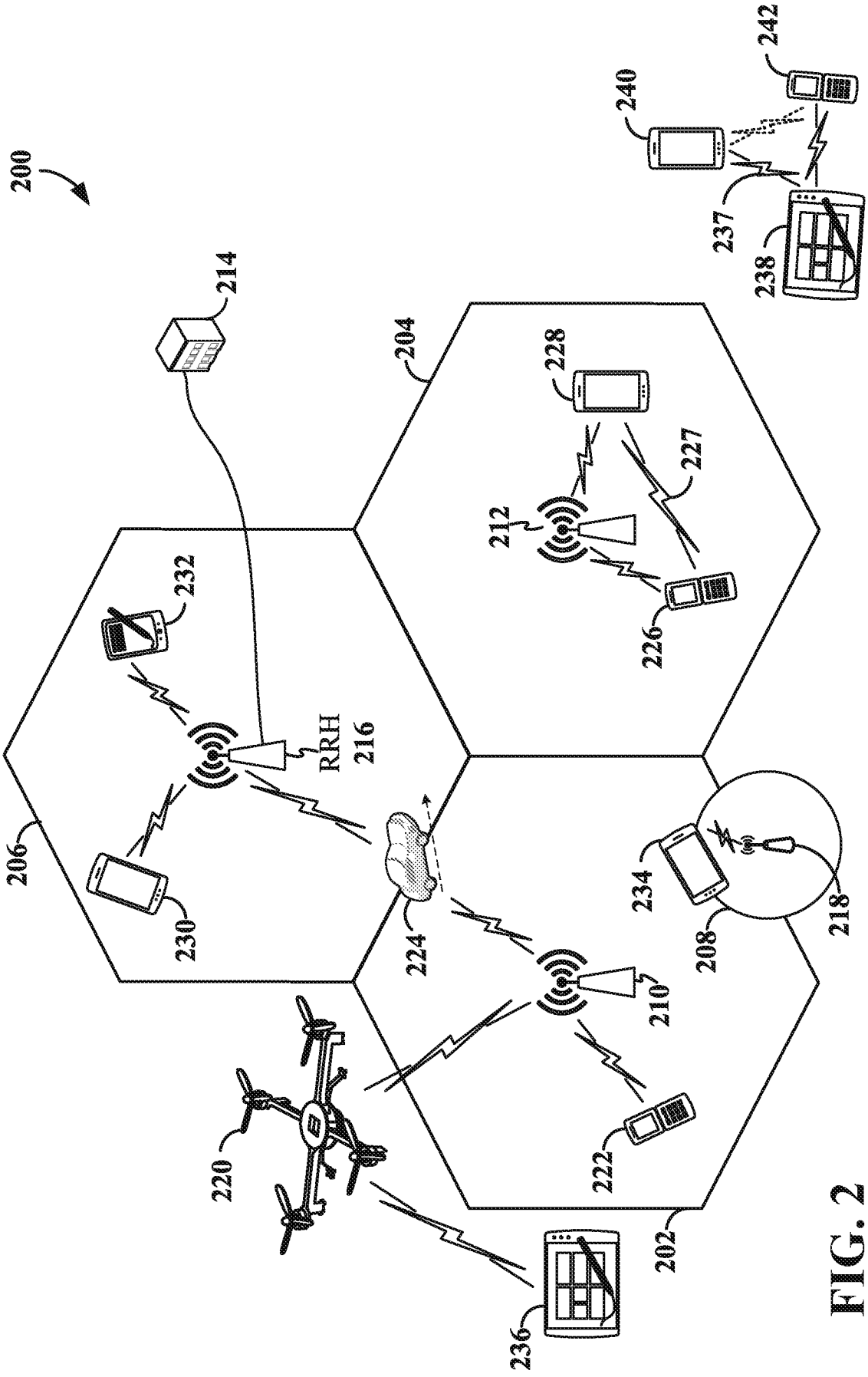

200
214
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232
RRH
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FIG. 2

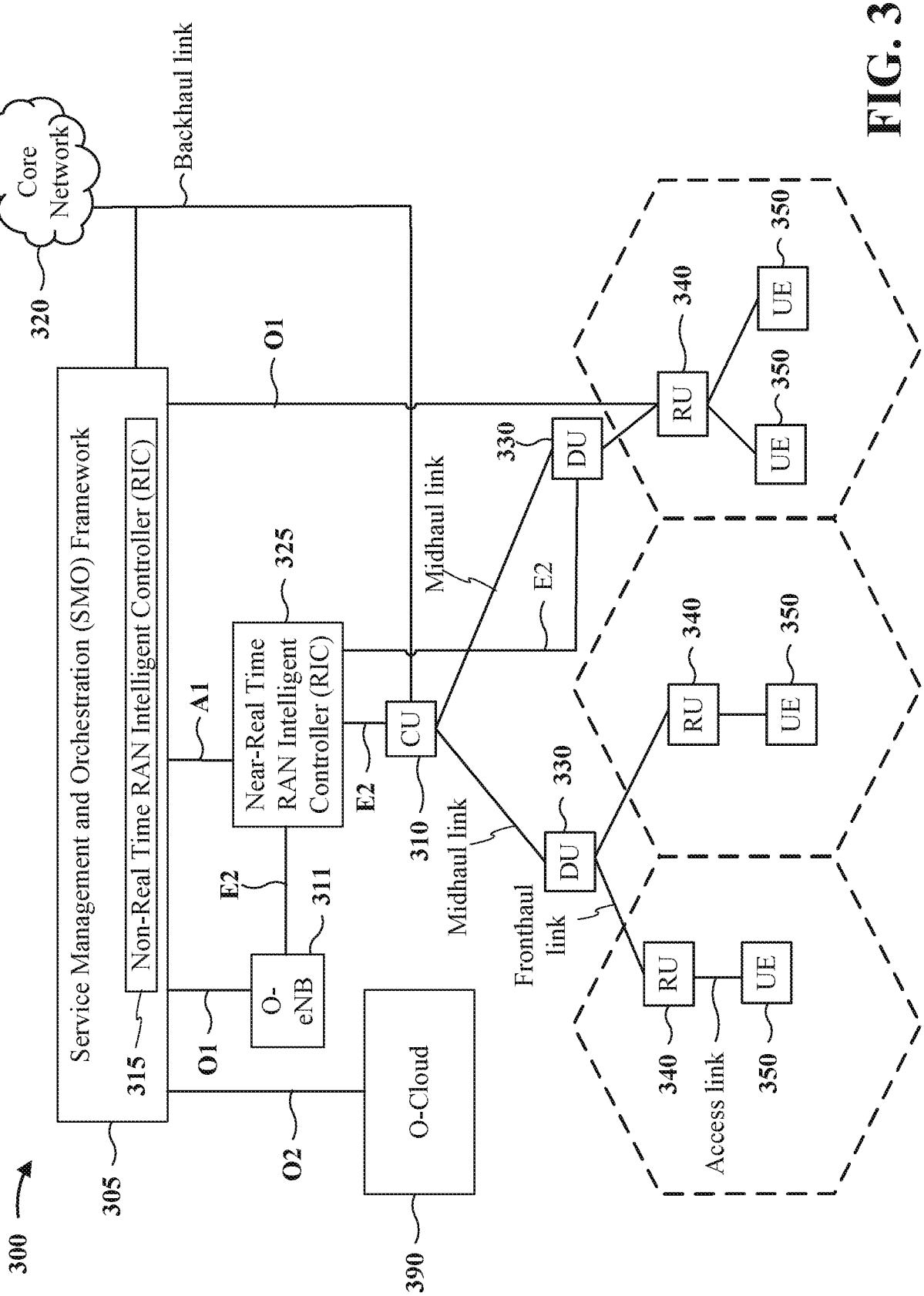

300
305
Service Management and Orchestration (SMO) Framework
315
Non-Real Time RAN Intelligent Controller (RIC)
A1
Near-Real Time RAN Intelligent Controller (RIC)
325
O1
O2
E2
311
O-eNB
O-Cloud
390
320
Core Network
Backhaul link
O1
E2
310
CU
Midhaul link
330
DU
Midhaul link
Fronthaul link
330
DU
E2
RU
340
UE
350
RU
340
UE
350
RU
340
UE
350
Access link

FIG. 3

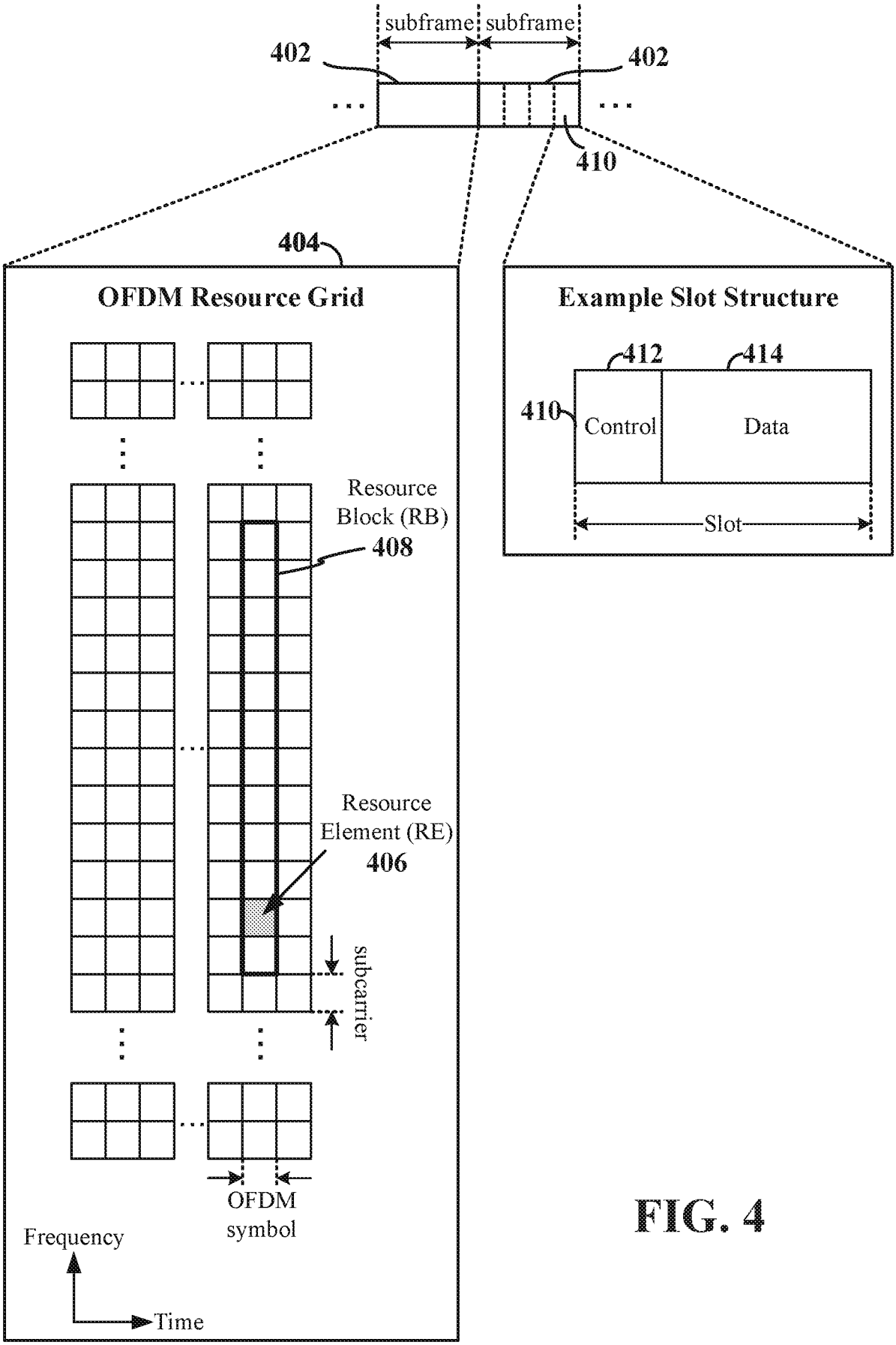

subframe
subframe
402
402
410
404
OFDM Resource Grid
Example Slot Structure
412
414
410
Control
Data
Slot
Resource Block (RB)
408
Resource Element (RE)
406
subcarrier
OFDM symbol
Frequency
Time

FIG. 4

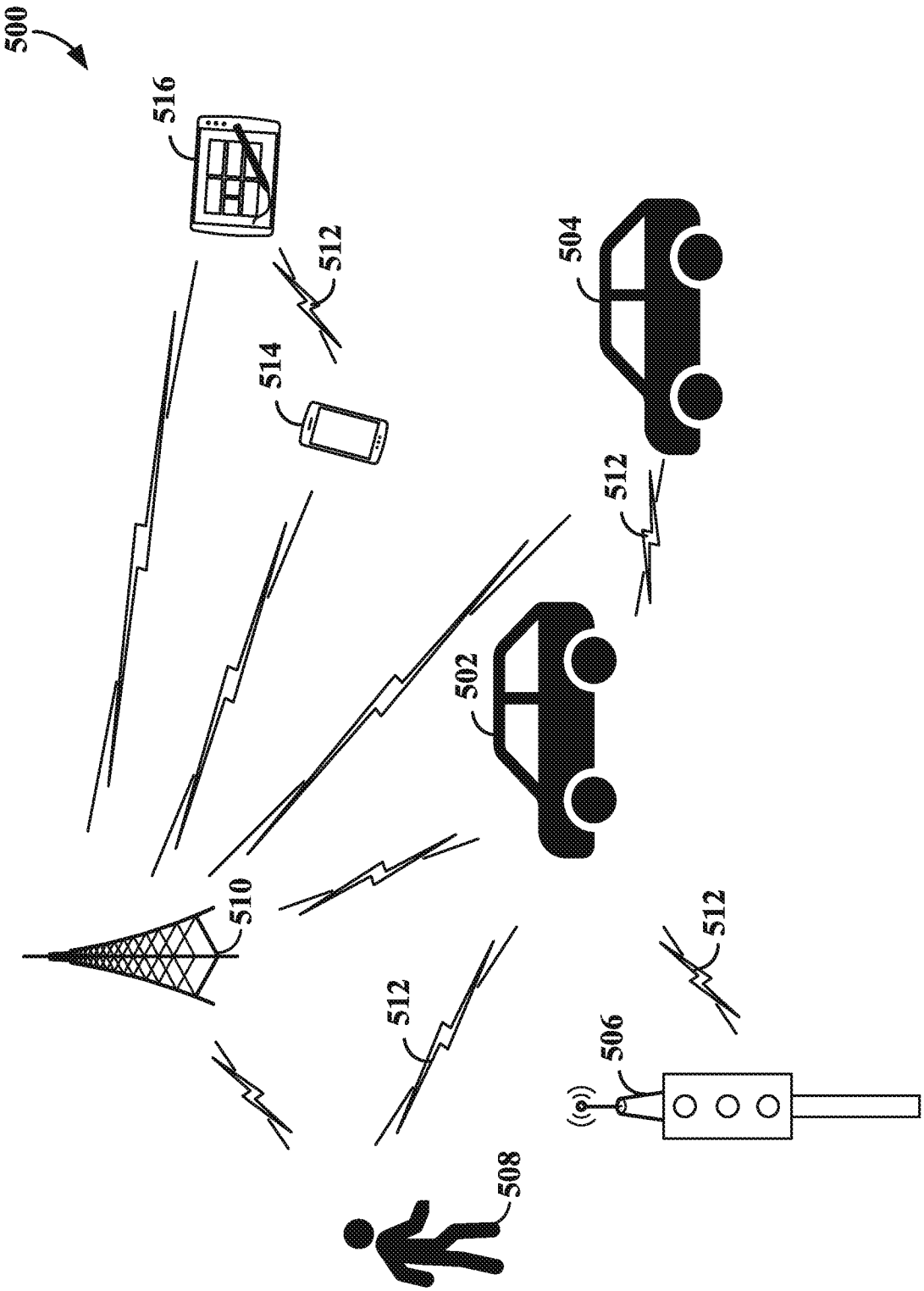


FIG. 5

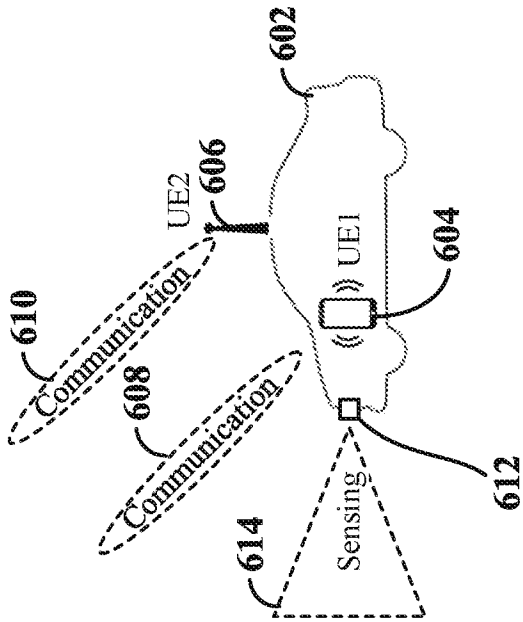

602
UE2
606
UE1
604
610
Communication
608
Communication
612
614
Sensing

FIG. 6

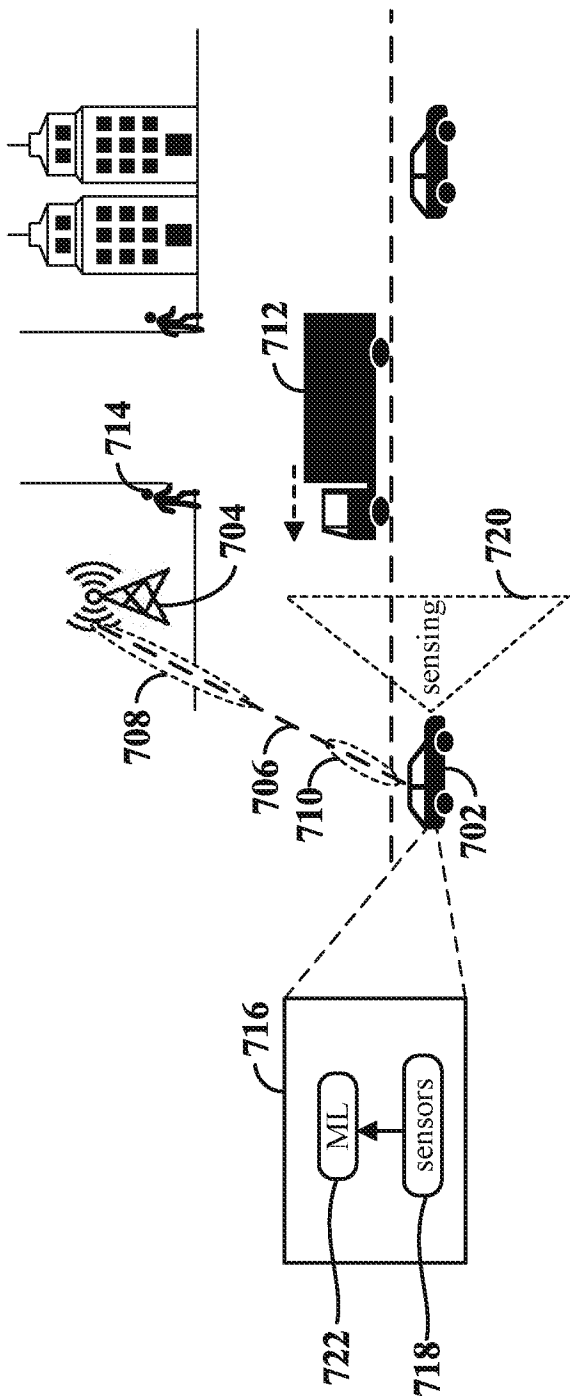


FIG. 7

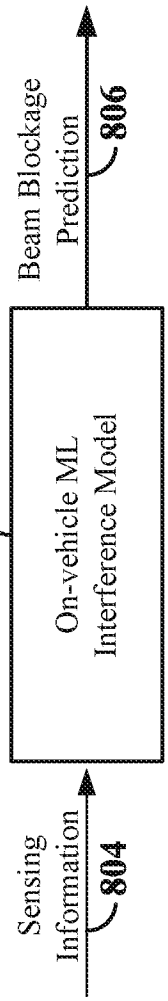

Sensing Information
804
802
On-vehicle ML Interference Model
Beam Blockage Prediction
806

FIG. 8

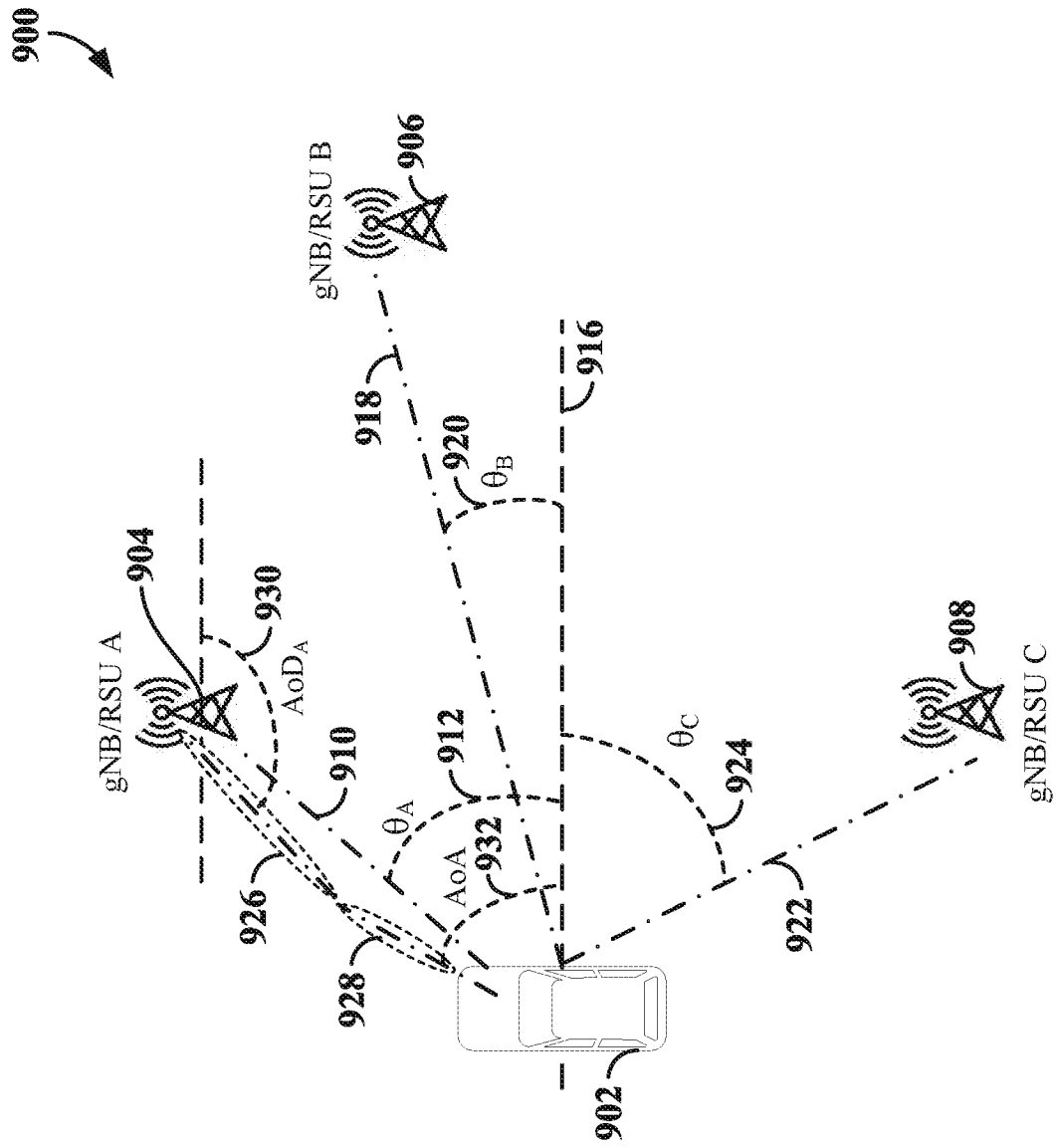

900
gNB/RSU A
904
930
AoD$_A$
910
912
θ_A
AoA
932
926
928
gNB/RSU B
906
918
920
θ_B
916
θ_C
924
922
908
gNB/RSU C
902

FIG. 9

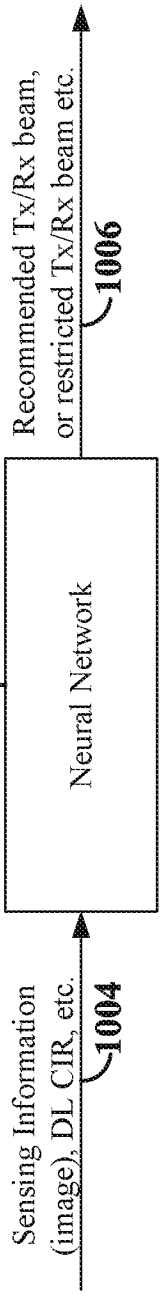

Sensing Information
(image), DL CIR, etc.
1004
1002
Neural Network
Recommended Tx/Rx beam,
or restricted Tx/Rx beam etc.
1006

FIG. 10

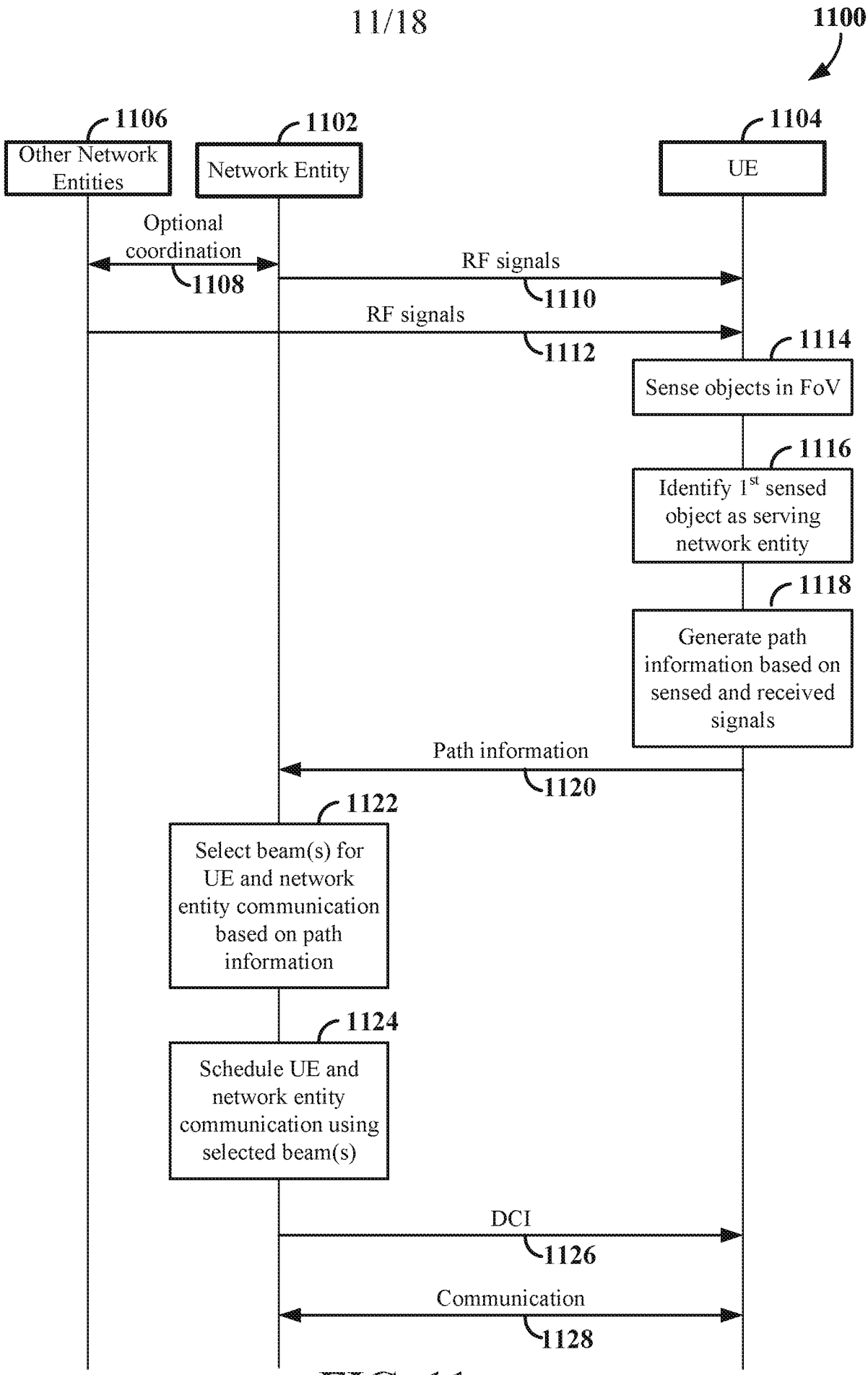

1100
1106
Other Network Entities
1102
Network Entity
1104
UE
Optional coordination
1108
RF signals
1110
RF signals
1112
1114
Sense objects in FoV
1116
Identify 1st sensed object as serving network entity
1118
Generate path information based on sensed and received signals
Path information
1120
1122
Select beam(s) for UE and network entity communication based on path information
1124
Schedule UE and network entity communication using selected beam(s)
DCI
1126
Communication
1128

FIG. 11

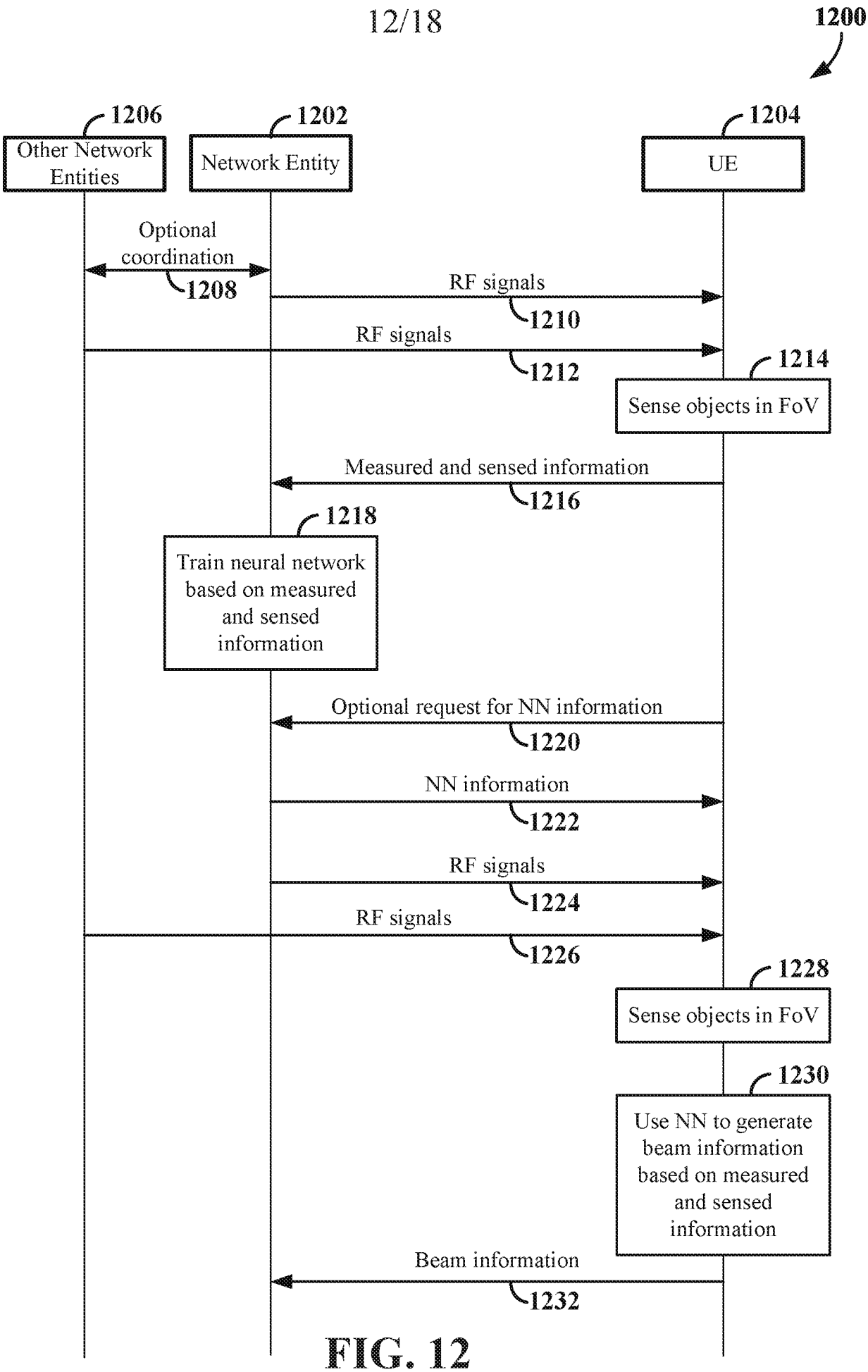

1200
1206
Other Network Entities
1202
Network Entity
1204
UE
Optional coordination
1208
RF signals
1210
RF signals
1212
1214
Sense objects in FoV
Measured and sensed information
1216
1218
Train neural network based on measured and sensed information
Optional request for NN information
1220
NN information
1222
RF signals
1224
RF signals
1226
1228
Sense objects in FoV
1230
Use NN to generate beam information based on measured and sensed information
Beam information
1232

FIG. 12

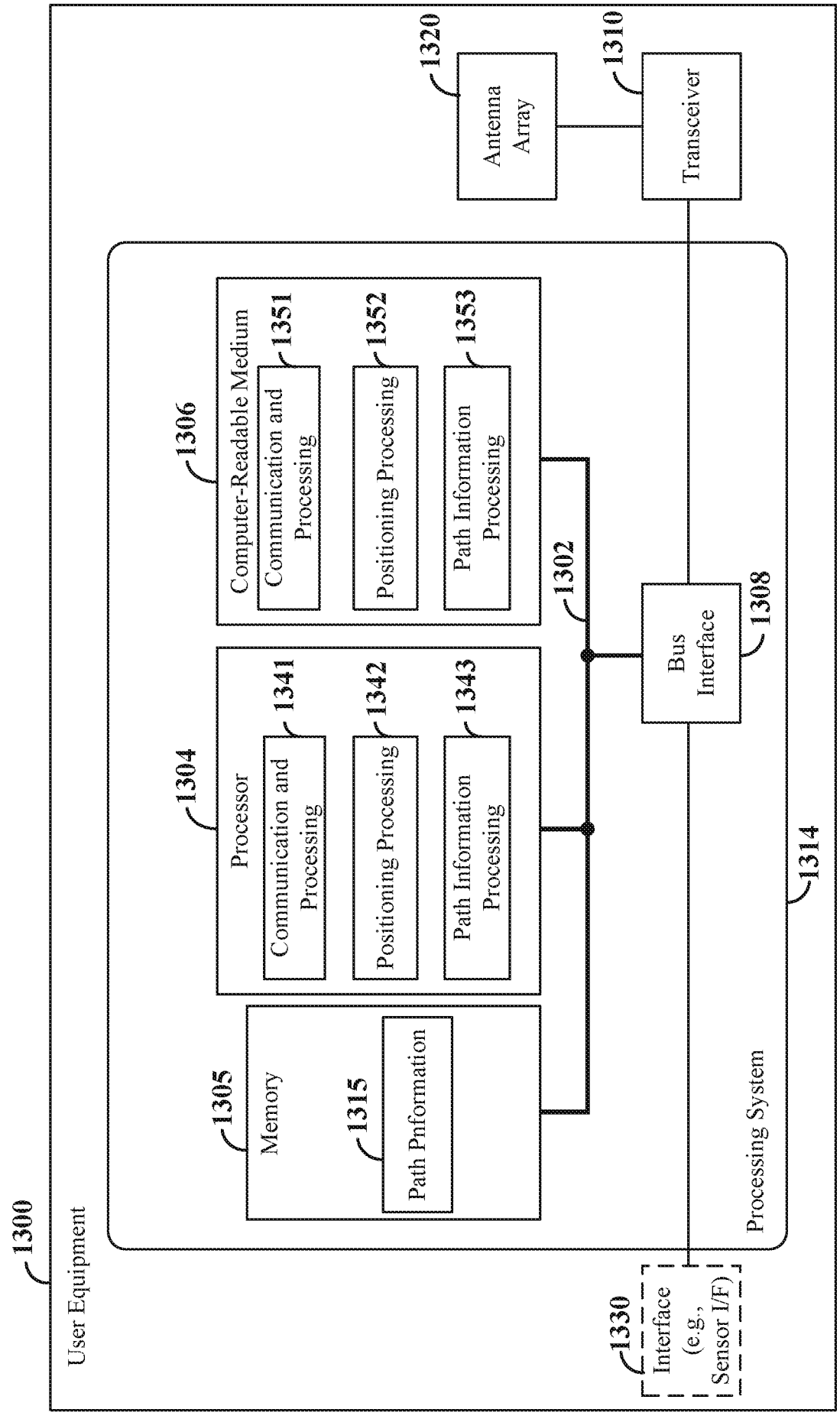

1300
User Equipment
1320
Antenna Array
1310
Transceiver
1306
Computer-Readable Medium
1351
Communication and Processing
1352
Positioning Processing
1353
Path Information Processing
1304
Processor
1341
Communication and Processing
1342
Positioning Processing
1343
Path Information Processing
1302
1305
Memory
1315
Path Pnformation
Bus Interface
1308
1314
Processing System
1330
Interface (e.g., Sensor I/F)

FIG. 13

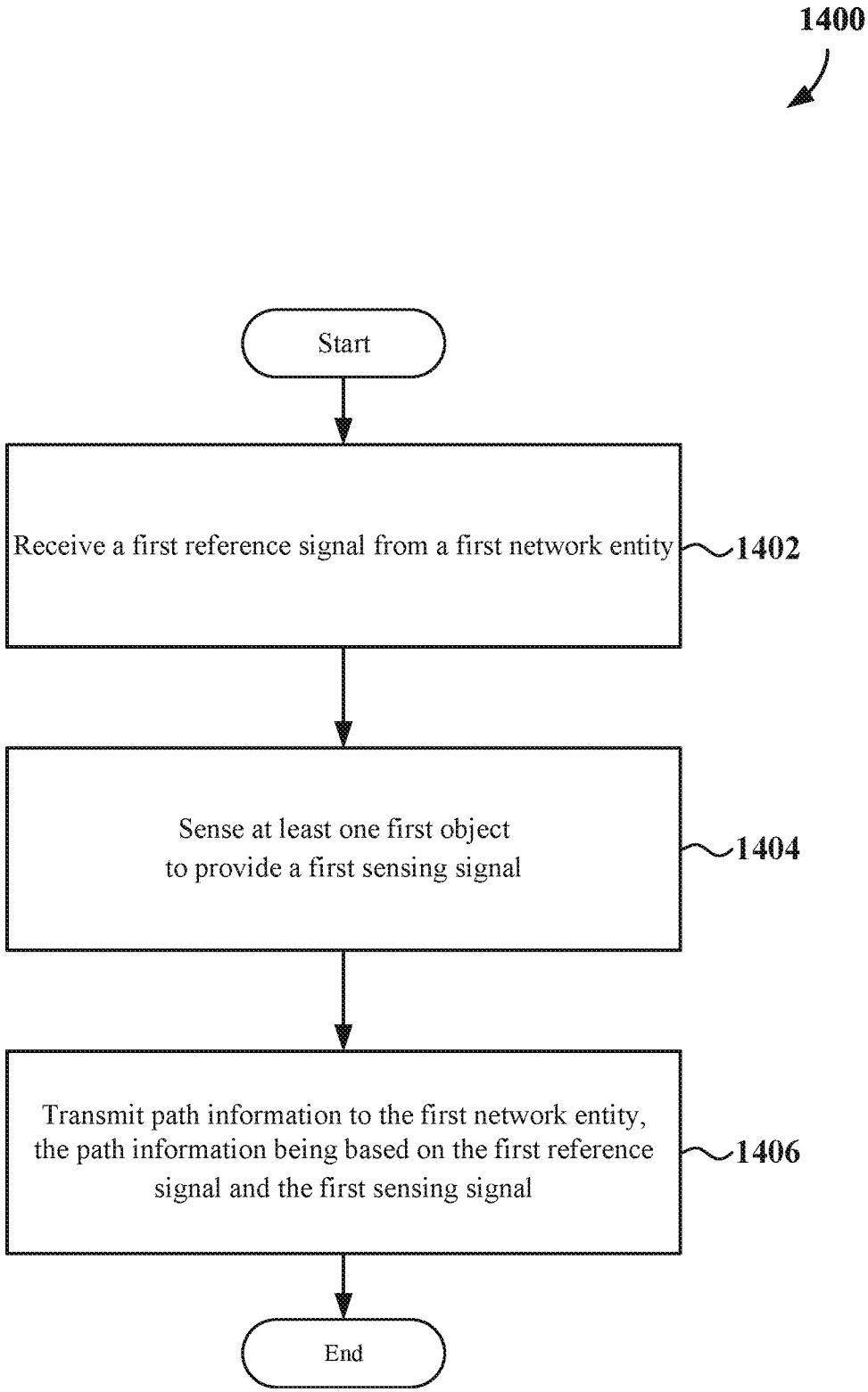

1400
Start
Receive a first reference signal from a first network entity
1402
Sense at least one first object
to provide a first sensing signal
1404
Transmit path information to the first network entity,
the path information being based on the first reference
signal and the first sensing signal
1406
End

FIG. 14

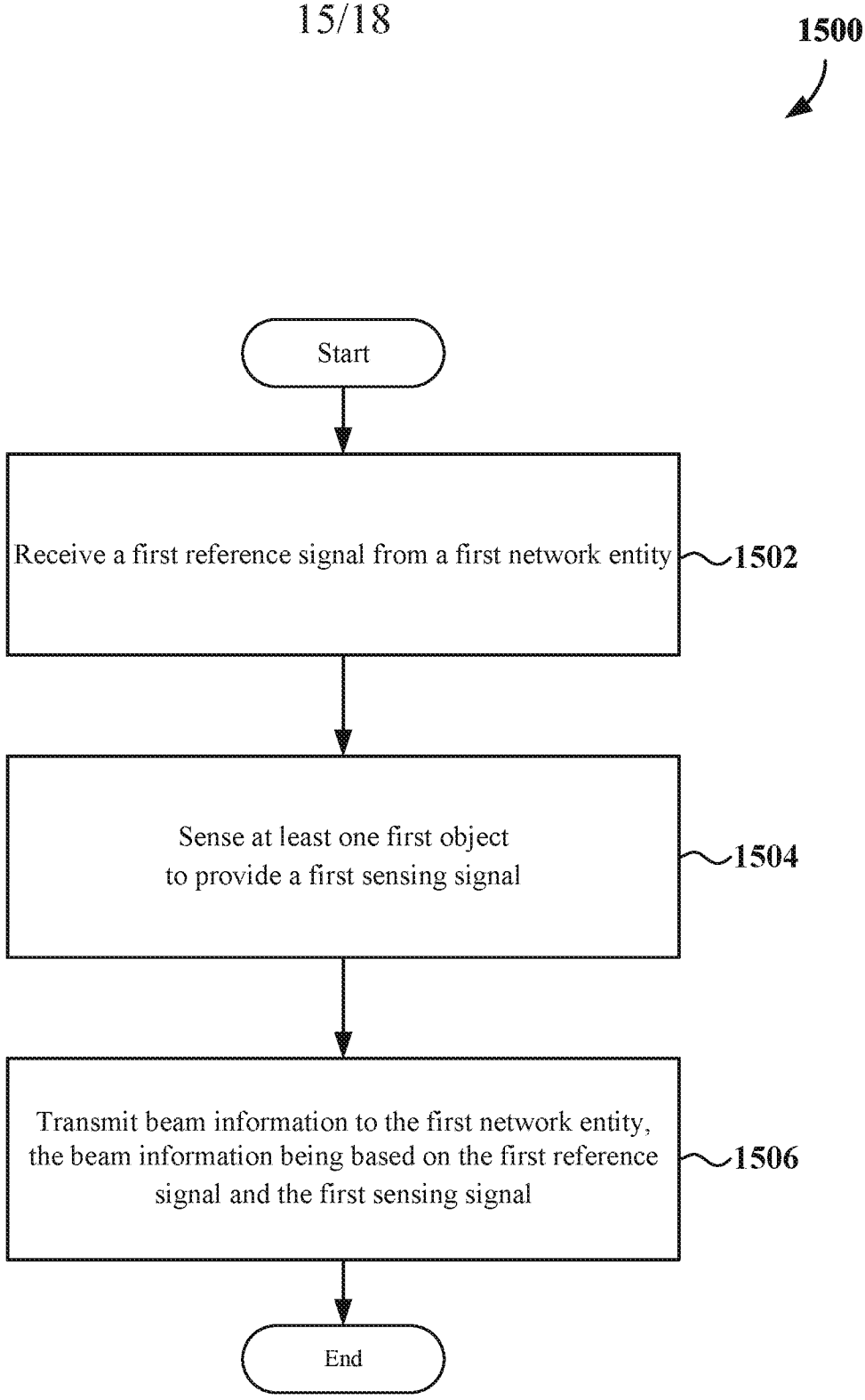

1500
Start
Receive a first reference signal from a first network entity
1502
Sense at least one first object
to provide a first sensing signal
1504
Transmit beam information to the first network entity,
the beam information being based on the first reference
signal and the first sensing signal
1506
End

FIG. 15

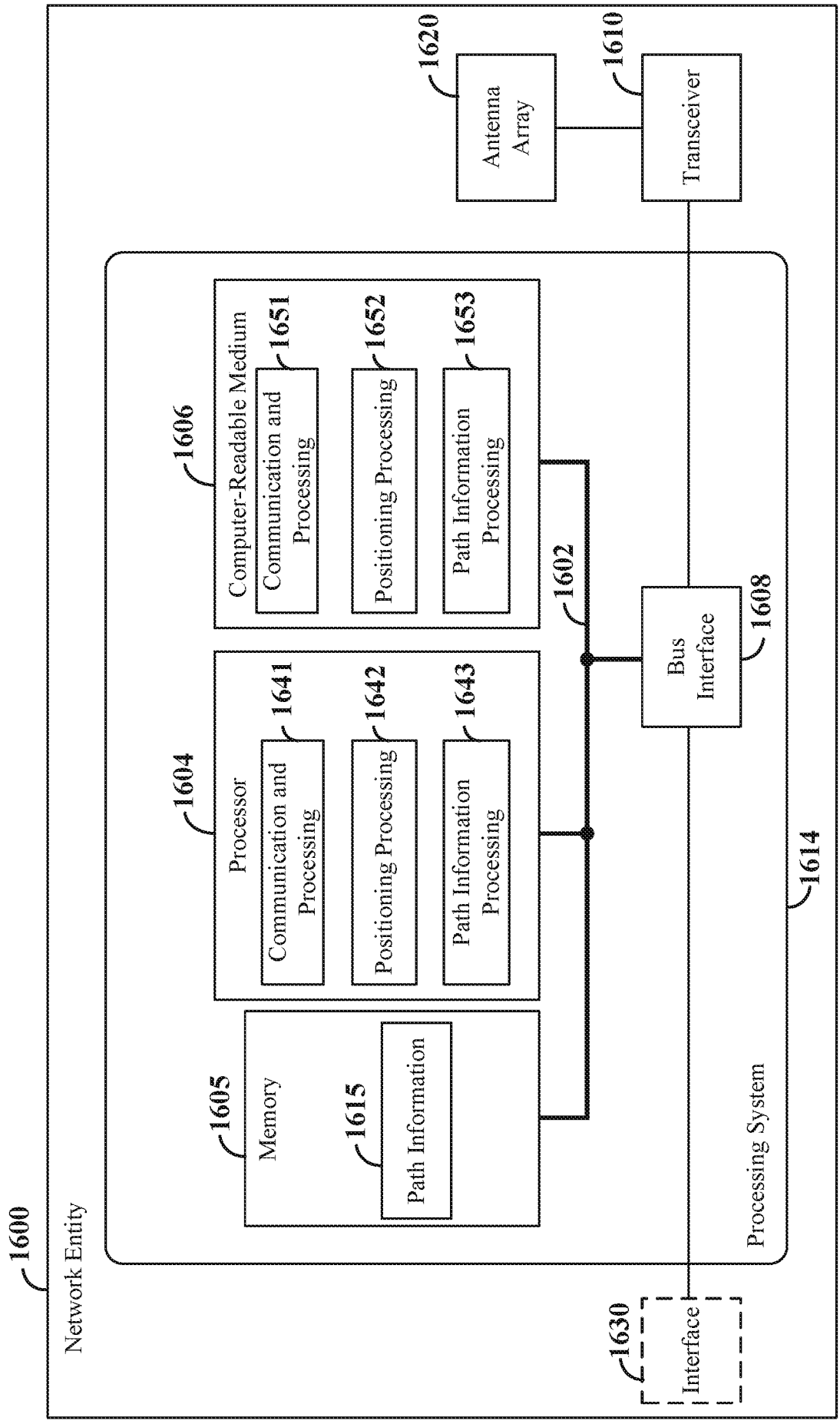

1600
Network Entity
1620
Antenna Array
1610
Transceiver
1606
Computer-Readable Medium
1651
Communication and Processing
1652
Positioning Processing
1653
Path Information Processing
1604
Processor
1641
Communication and Processing
1642
Positioning Processing
1643
Path Information Processing
1602
1605
Memory
1615
Path Information
Bus Interface
1608
1614
Processing System
1630
Interface

FIG. 16

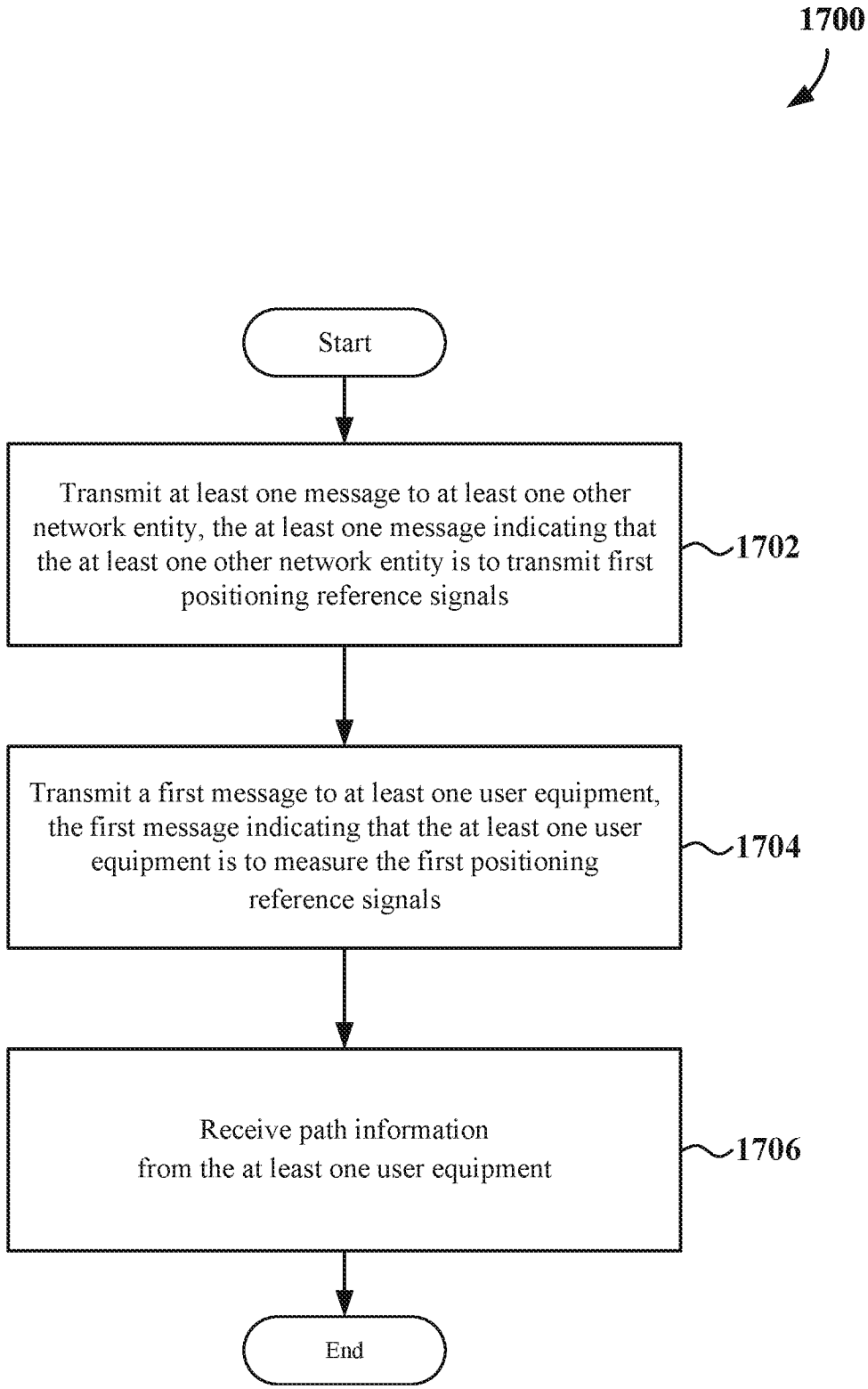

1700
Start
Transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals
1702
Transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals
1704
Receive path information from the at least one user equipment
1706
End

FIG. 17

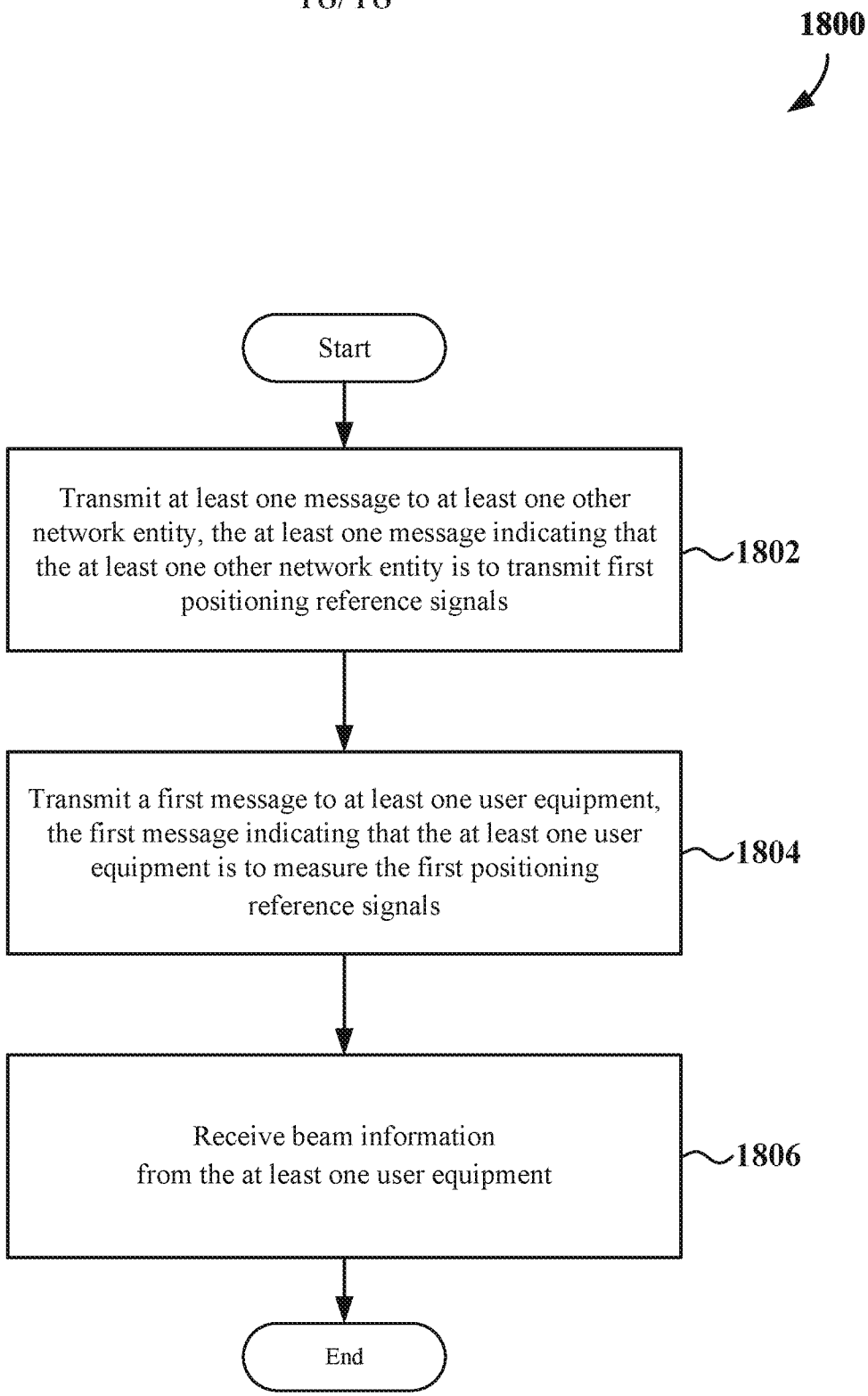

1800
Start
Transmit at least one message to at least one other network entity, the at least one message indicating that the at least one other network entity is to transmit first positioning reference signals
1802
Transmit a first message to at least one user equipment, the first message indicating that the at least one user equipment is to measure the first positioning reference signals
1804
Receive beam information from the at least one user equipment
1806
End

FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/119807

A. CLASSIFICATION OF SUBJECT MATTER

H04W64/00(2009.01)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)

IPC:H04W G01S

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)

CNTXT; CNKI; ENTXTC; DWPI; 3GPP: reference signal, positioning reference signal, RS, PRS, measure, sensing signal, path information, beam, pathloss

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021341562 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 04 November 2021 (2021-11-04) description, paragraphs [0127]-[0153]	20,22-27,30
A	US 2021341562 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 04 November 2021 (2021-11-04) description, paragraphs [0127]-[0153]	1-19,21,28-29
X	WO 2021243580 A1 (BEIJING XIAOMI MOBILE SOFTWARE CO., LTD.) 09 December 2021 (2021-12-09) description, paragraphs [0224]-[0298]	20,22-27,30
A	WO 2021243580 A1 (BEIJING XIAOMI MOBILE SOFTWARE CO., LTD.) 09 December 2021 (2021-12-09) description, paragraphs [0224]-[0298]	1-19,21,28-29
A	WO 2022022138 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 03 February 2022 (2022-02-03) the whole document	1-30

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

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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	Date of mailing of the international search report
17 May 2023	**23 May 2023**

Name and mailing address of the ISA/CN	Authorized officer
CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**LIN,GuiRong** Telephone No. **(+86) 010-53961573**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2022022534 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 03 February 2022 (2022-02-03) the whole document	1-30
A	WO 2022133933 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 30 June 2022 (2022-06-30) the whole document	1-30
A	ZTE et al. "Channel sensing based schemes for cross-link interference mitigation in NR" *3GPP TSG RAN WG1 Meeting #88 R1-1701617*, 17 February 2017 (2017-02-17), the whole document	1-30

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/119807

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2021341562	A1	04 November 2021	EP	3861363	A1	11 August 2021
				JP	2022502957	A	11 January 2022
				WO	2020071992	A1	09 April 2020
				CN	113167850	A	23 July 2021
WO	2021243580	A1	09 December 2021	BR	112022024333	A2	17 January 2023
				EP	4161174	A1	05 April 2023
				KR	20230016659	A	02 February 2023
				CN	111819893	A	23 October 2020
				IN	202247076918	A	06 January 2023
WO	2022022138	A1	03 February 2022	CN	114007181	A	01 February 2022
WO	2022022534	A1	03 February 2022	BR	112023001390	A2	14 February 2023
				CN	115804170	A	14 March 2023
WO	2022133933	A1	30 June 2022	None			