



(51) International Patent Classification:

G01S 5/02 (2010.01)

(21) International Application Number:

PCT/US2022/013824

(22) International Filing Date:

26 January 2022 (26.01.2022)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

20210100169 17 March 2021 (17.03.2021) GR

(71) Applicant: QUALCOMM INCORPORATED [US/US];

ATTN: International IP Administration, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(72) Inventors: DUAN, Weimin; QUALCOMM Incorporated,

5775 Morehouse Drive, San Diego, California 92121-1714 (US). MANOLAKOS, Alexandros; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). MUKKAVILLI, Krishna Kiran;

QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). CHEN, Wanshi; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). BHUSHAN, Naga; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). SUNDARARAJAN, Jay Kumar; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US). PARK, Seyong; QUALCOMM Incorporated, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(74) Agent: OLDS, Mark E.; MUNCY, GEISSLER, OLDS & LOWE, P.C., 4000 Legato Road, Suite 310, Fairfax, Virginia 22033 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO,

(54) Title: LOCATION ASSISTANCE DATA FOR RECONFIGURABLE INTELLIGENT SURFACE AIDED POSITIONING

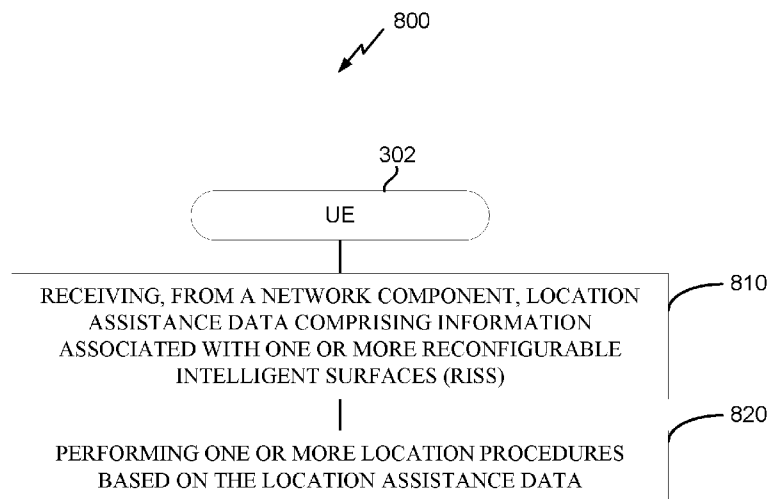


FIG. 8

(57) Abstract: Disclosed are techniques for communication. In an aspect, a network component determines location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs). The network component transmits, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data. The UE receives the location assistance data and performs the one or more location procedures based on the location assistance data.



NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW,
SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

LOCATION ASSISTANCE DATA FOR RECONFIGURABLE INTELLIGENT SURFACE AIDED POSITIONING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present Application for Patent claims the benefit of GR Application No. 20210100169, entitled “LOCATION ASSISTANCE DATA FOR RECONFIGURABLE INTELLIGENT SURFACE AIDED POSITIONING”, filed March 17, 2021, which is assigned to the assignee hereof, and is expressly incorporated herein by reference in its entirety.

BACKGROUND OF THE DISCLOSURE

1. *Field of the Disclosure*

[0002] Aspects of the disclosure relate generally to wireless communications.

2. *Description of the Related Art*

[0003] Wireless communication systems have developed through various generations, including a first-generation analog wireless phone service (1G), a second-generation (2G) digital wireless phone service (including interim 2.5G and 2.75G networks), a third-generation (3G) high speed data, Internet-capable wireless service and a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax). There are presently many different types of wireless communication systems in use, including cellular and personal communications service (PCS) systems. Examples of known cellular systems include the cellular analog advanced mobile phone system (AMPS), and digital cellular systems based on code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), the Global System for Mobile communications (GSM), etc.

[0004] A fifth generation (5G) wireless standard, referred to as New Radio (NR), calls for higher data transfer speeds, greater numbers of connections, and better coverage, among other improvements. The 5G standard, according to the Next Generation Mobile Networks Alliance, is designed to provide data rates of several tens of megabits per second to each of tens of thousands of users, with 1 gigabit

per second to tens of workers on an office floor. Several hundreds of thousands of simultaneous connections should be supported in order to support large sensor deployments. Consequently, the spectral efficiency of 5G mobile communications should be significantly enhanced compared to the current 4G standard. Furthermore, signaling efficiencies should be enhanced and latency should be substantially reduced compared to current standards.

SUMMARY

[0005] The following presents a simplified summary relating to one or more aspects disclosed herein. Thus, the following summary should not be considered an extensive overview relating to all contemplated aspects, nor should the following summary be considered to identify key or critical elements relating to all contemplated aspects or to delineate the scope associated with any particular aspect. Accordingly, the following summary has the sole purpose to present certain concepts relating to one or more aspects relating to the mechanisms disclosed herein in a simplified form to precede the detailed description presented below.

[0006] In an aspect, a method of operating a user equipment (UE) includes receiving, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and performing one or more location procedures based on the location assistance data.

[0007] In an aspect, a method of operating a network component includes determining location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and transmitting, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

[0008] In an aspect, a user equipment (UE) includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: receive, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and perform one or more location procedures based on the location assistance data.

[0009] In an aspect, a network component includes a memory; at least one transceiver; and at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to: determine location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and transmit, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

[0010] In an aspect, a user equipment (UE) includes means for receiving, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and means for performing one or more location procedures based on the location assistance data.

[0011] In an aspect, a network component includes means for determining location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and means for transmitting, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

[0012] In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to: receive, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and perform one or more location procedures based on the location assistance data.

[0013] In an aspect, a non-transitory computer-readable medium storing computer-executable instructions that, when executed by a network component, cause the network component to: determine location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and transmit, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

[0014] Other objects and advantages associated with the aspects disclosed herein will be apparent to those skilled in the art based on the accompanying drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The accompanying drawings are presented to aid in the description of various aspects of the disclosure and are provided solely for illustration of the aspects and not limitation thereof.

[0016] FIG. 1 illustrates an example wireless communications system, according to aspects of the disclosure.

[0017] FIGS. 2A and 2B illustrate example wireless network structures, according to aspects of the disclosure.

[0018] FIGS. 3A to 3C are simplified block diagrams of several sample aspects of components that may be employed in a user equipment (UE), a base station, and a network entity, respectively, and configured to support communications as taught herein.

[0019] FIGS. 4A to 4D are diagrams illustrating example frame structures and channels within the frame structures, according to aspects of the disclosure.

[0020] FIG. 5 is a diagram illustrating an example base station in communication with an example UE, according to aspects of the disclosure.

[0021] FIG. 6 illustrates an example system for wireless communication using a reconfigurable intelligent surface (RIS), according to aspects of the disclosure.

[0022] FIG. 7 is a diagram of an example architecture of a RIS, according to aspects of the disclosure.

[0023] FIG. 8 illustrates an exemplary process of communications according to an aspect of the disclosure.

[0024] FIG. 9 illustrates an exemplary process of communications according to another aspect of the disclosure.

[0025] FIG. 10 illustrates an arrangement by which boresight can be derived according to an aspect of the disclosure.

DETAILED DESCRIPTION

[0026] Aspects of the disclosure are provided in the following description and related drawings directed to various examples provided for illustration purposes. Alternate aspects may be devised without departing from the scope of the disclosure. Additionally, well-known elements of the disclosure will not be described in detail or will be omitted so as not to obscure the relevant details of the disclosure.

[0027] The words “exemplary” and/or “example” are used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” and/or “example” is not necessarily to be construed as preferred or advantageous over other aspects. Likewise, the term “aspects of the disclosure” does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation.

[0028] Those of skill in the art will appreciate that the information and signals described below may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description below may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof, depending in part on the particular application, in part on the desired design, in part on the corresponding technology, etc.

[0029] Further, many aspects are described in terms of sequences of actions to be performed by, for example, elements of a computing device. It will be recognized that various actions described herein can be performed by specific circuits (e.g., application specific integrated circuits (ASICs)), by program instructions being executed by one or more processors, or by a combination of both. Additionally, the sequence(s) of actions described herein can be considered to be embodied entirely within any form of non-transitory computer-readable storage medium having stored therein a corresponding set of computer instructions that, upon execution, would cause or instruct an associated processor of a device to perform the functionality described herein. Thus, the various aspects of the disclosure may be embodied in a number of different forms, all of which have been contemplated to be within the scope of the claimed subject matter. In addition, for each of the aspects described herein, the corresponding form of any such aspects may be described herein as, for example, “logic configured to” perform the described action.

[0030] As used herein, the terms “user equipment” (UE) and “base station” are not intended to be specific or otherwise limited to any particular radio access technology (RAT), unless otherwise noted. In general, a UE may be any wireless communication device (e.g., a mobile phone, router, tablet computer, laptop

computer, consumer asset tracking device, wearable (e.g., smartwatch, glasses, augmented reality (AR) / virtual reality (VR) headset, etc.), vehicle (e.g., automobile, motorcycle, bicycle, etc.), Internet of Things (IoT) device, etc.) used by a user to communicate over a wireless communications network. A UE may be mobile or may (e.g., at certain times) be stationary, and may communicate with a radio access network (RAN). As used herein, the term “UE” may be referred to interchangeably as an “access terminal” or “AT,” a “client device,” a “wireless device,” a “subscriber device,” a “subscriber terminal,” a “subscriber station,” a “user terminal” or “UT,” a “mobile device,” a “mobile terminal,” a “mobile station,” or variations thereof. Generally, UEs can communicate with a core network via a RAN, and through the core network the UEs can be connected with external networks such as the Internet and with other UEs. Of course, other mechanisms of connecting to the core network and/or the Internet are also possible for the UEs, such as over wired access networks, wireless local area network (WLAN) networks (e.g., based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 specification, etc.) and so on.

[0031] A base station may operate according to one of several RATs in communication with UEs depending on the network in which it is deployed, and may be alternatively referred to as an access point (AP), a network node, a NodeB, an evolved NodeB (eNB), a next generation eNB (ng-eNB), a New Radio (NR) Node B (also referred to as a gNB or gNodeB), etc. A base station may be used primarily to support wireless access by UEs, including supporting data, voice, and/or signaling connections for the supported UEs. In some systems a base station may provide purely edge node signaling functions while in other systems it may provide additional control and/or network management functions. A communication link through which UEs can send signals to a base station is called an uplink (UL) channel (e.g., a reverse traffic channel, a reverse control channel, an access channel, etc.). A communication link through which the base station can send signals to UEs is called a downlink (DL) or forward link channel (e.g., a paging channel, a control channel, a broadcast channel, a forward traffic channel, etc.). As used herein the term traffic channel (TCH) can refer to either an uplink / reverse or downlink / forward traffic channel.

[0032] The term “base station” may refer to a single physical transmission-reception point (TRP) or to multiple physical TRPs that may or may not be co-located. For example, where the term “base station” refers to a single physical TRP, the physical TRP may be an antenna of the base station corresponding to a cell (or several cell sectors) of the base station. Where the term “base station” refers to multiple co-located physical TRPs, the physical TRPs may be an array of antennas (e.g., as in a multiple-input multiple-output (MIMO) system or where the base station employs beamforming) of the base station. Where the term “base station” refers to multiple non-co-located physical TRPs, the physical TRPs may be a distributed antenna system (DAS) (a network of spatially separated antennas connected to a common source via a transport medium) or a remote radio head (RRH) (a remote base station connected to a serving base station). Alternatively, the non-co-located physical TRPs may be the serving base station receiving the measurement report from the UE and a neighbor base station whose reference radio frequency (RF) signals the UE is measuring. Because a TRP is the point from which a base station transmits and receives wireless signals, as used herein, references to transmission from or reception at a base station are to be understood as referring to a particular TRP of the base station.

[0033] In some implementations that support positioning of UEs, a base station may not support wireless access by UEs (e.g., may not support data, voice, and/or signaling connections for UEs), but may instead transmit reference signals to UEs to be measured by the UEs, and/or may receive and measure signals transmitted by the UEs. Such a base station may be referred to as a positioning beacon (e.g., when transmitting signals to UEs) and/or as a location measurement unit (e.g., when receiving and measuring signals from UEs).

[0034] An “RF signal” comprises an electromagnetic wave of a given frequency that transports information through the space between a transmitter and a receiver. As used herein, a transmitter may transmit a single “RF signal” or multiple “RF signals” to a receiver. However, the receiver may receive multiple “RF signals” corresponding to each transmitted RF signal due to the propagation characteristics of RF signals through multipath channels. The same transmitted RF signal on different paths between the transmitter and receiver may be referred to as a “multipath” RF signal.

[0035] FIG. 1 illustrates an example wireless communications system 100, according to aspects of the disclosure. The wireless communications system 100 (which may also be referred to as a wireless wide area network (WWAN)) may include various base stations 102 (labeled “BS”) and various UEs 104. The base stations 102 may include macro cell base stations (high power cellular base stations) and/or small cell base stations (low power cellular base stations). In an aspect, the macro cell base station may include eNBs and/or ng-eNBs where the wireless communications system 100 corresponds to an LTE network, or gNBs where the wireless communications system 100 corresponds to a NR network, or a combination of both, and the small cell base stations may include femtocells, picocells, microcells, etc.

[0036] The base stations 102 may collectively form a RAN and interface with a core network 170 (e.g., an evolved packet core (EPC) or a 5G core (5GC)) through backhaul links 122, and through the core network 170 to one or more location servers 172 (e.g., a location management function (LMF) or a secure user plane location (SUPL) location platform (SLP)). The location server(s) 172 may be part of core network 170 or may be external to core network 170. In addition to other functions, the base stations 102 may perform functions that relate to one or more of transferring user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, RAN sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate with each other directly or indirectly (e.g., through the EPC / 5GC) over backhaul links 134, which may be wired or wireless.

[0037] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. In an aspect, one or more cells may be supported by a base station 102 in each geographic coverage area 110. A “cell” is a logical communication entity used for communication with a base station (e.g., over some frequency resource, referred to as a carrier frequency, component

carrier, carrier, band, or the like), and may be associated with an identifier (e.g., a physical cell identifier (PCI), a virtual cell identifier (VCI), a cell global identifier (CGI)) for distinguishing cells operating via the same or a different carrier frequency. In some cases, different cells may be configured according to different protocol types (e.g., machine-type communication (MTC), narrowband IoT (NB-IoT), enhanced mobile broadband (eMBB), or others) that may provide access for different types of UEs. Because a cell is supported by a specific base station, the term “cell” may refer to either or both of the logical communication entity and the base station that supports it, depending on the context. In some cases, the term “cell” may also refer to a geographic coverage area of a base station (e.g., a sector), insofar as a carrier frequency can be detected and used for communication within some portion of geographic coverage areas 110.

[0038] While neighboring macro cell base station 102 geographic coverage areas 110 may partially overlap (e.g., in a handover region), some of the geographic coverage areas 110 may be substantially overlapped by a larger geographic coverage area 110. For example, a small cell (SC) base station 102' may have a geographic coverage area 110' that substantially overlaps with the geographic coverage area 110 of one or more macro cell base stations 102. A network that includes both small cell and macro cell base stations may be known as a heterogeneous network. A heterogeneous network may also include home eNBs (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG).

[0039] The communication links 120 between the base stations 102 and the UEs 104 may include uplink (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use MIMO antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links 120 may be through one or more carrier frequencies. Allocation of carriers may be asymmetric with respect to downlink and uplink (e.g., more or less carriers may be allocated for downlink than for uplink).

[0040] The wireless communications system 100 may further include a wireless local area network (WLAN) access point (AP) 150 in communication with WLAN

stations (STAs) 152 via communication links 154 in an unlicensed frequency spectrum (e.g., 5 GHz). When communicating in an unlicensed frequency spectrum, the WLAN STAs 152 and/or the WLAN AP 150 may perform a clear channel assessment (CCA) or listen before talk (LBT) procedure prior to communicating in order to determine whether the channel is available.

[0041] The small cell base station 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell base station 102' may employ LTE or NR technology and use the same 5 GHz unlicensed frequency spectrum as used by the WLAN AP 150. The small cell base station 102', employing LTE / 5G in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network. NR in unlicensed spectrum may be referred to as NR-U. LTE in an unlicensed spectrum may be referred to as LTE-U, licensed assisted access (LAA), or MulteFire.

[0042] The wireless communications system 100 may further include a millimeter wave (mmW) base station 180 that may operate in mmW frequencies and/or near mmW frequencies in communication with a UE 182. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in this band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW/near mmW radio frequency band have high path loss and a relatively short range. The mmW base station 180 and the UE 182 may utilize beamforming (transmit and/or receive) over a mmW communication link 184 to compensate for the extremely high path loss and short range. Further, it will be appreciated that in alternative configurations, one or more base stations 102 may also transmit using mmW or near mmW and beamforming. Accordingly, it will be appreciated that the foregoing illustrations are merely examples and should not be construed to limit the various aspects disclosed herein.

[0043] Transmit beamforming is a technique for focusing an RF signal in a specific direction. Traditionally, when a network node (e.g., a base station)

broadcasts an RF signal, it broadcasts the signal in all directions (omni-directionally). With transmit beamforming, the network node determines where a given target device (e.g., a UE) is located (relative to the transmitting network node) and projects a stronger downlink RF signal in that specific direction, thereby providing a faster (in terms of data rate) and stronger RF signal for the receiving device(s). To change the directionality of the RF signal when transmitting, a network node can control the phase and relative amplitude of the RF signal at each of the one or more transmitters that are broadcasting the RF signal. For example, a network node may use an array of antennas (referred to as a “phased array” or an “antenna array”) that creates a beam of RF waves that can be “steered” to point in different directions, without actually moving the antennas. Specifically, the RF current from the transmitter is fed to the individual antennas with the correct phase relationship so that the radio waves from the separate antennas add together to increase the radiation in a desired direction, while cancelling to suppress radiation in undesired directions.

[0044] Transmit beams may be quasi-co-located, meaning that they appear to the receiver (e.g., a UE) as having the same parameters, regardless of whether or not the transmitting antennas of the network node themselves are physically co-located. In NR, there are four types of quasi-co-location (QCL) relations. Specifically, a QCL relation of a given type means that certain parameters about a target reference RF signal on a target beam can be derived from information about a source reference RF signal on a source beam. If the source reference RF signal is QCL Type A, the receiver can use the source reference RF signal to estimate the Doppler shift, Doppler spread, average delay, and delay spread of a target reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type B, the receiver can use the source reference RF signal to estimate the Doppler shift and Doppler spread of a target reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type C, the receiver can use the source reference RF signal to estimate the Doppler shift and average delay of a target reference RF signal transmitted on the same channel. If the source reference RF signal is QCL Type D, the receiver can use the source reference RF signal to estimate the spatial receive parameter of a target reference RF signal transmitted on the same channel.

[0045] In receive beamforming, the receiver uses a receive beam to amplify RF signals detected on a given channel. For example, the receiver can increase the gain setting and/or adjust the phase setting of an array of antennas in a particular direction to amplify (e.g., to increase the gain level of) the RF signals received from that direction. Thus, when a receiver is said to beamform in a certain direction, it means the beam gain in that direction is high relative to the beam gain along other directions, or the beam gain in that direction is the highest compared to the beam gain in that direction of all other receive beams available to the receiver. This results in a stronger received signal strength (e.g., reference signal received power (RSRP), reference signal received quality (RSRQ), signal-to-interference-plus-noise ratio (SINR), etc.) of the RF signals received from that direction.

[0046] Receive beams may be spatially related. A spatial relation means that parameters for a transmit beam for a second reference signal can be derived from information about a receive beam for a first reference signal. For example, a UE may use a particular receive beam to receive one or more reference downlink reference signals (e.g., positioning reference signals (PRS), tracking reference signals (TRS), phase tracking reference signal (PTRS), cell-specific reference signals (CRS), channel state information reference signals (CSI-RS), primary synchronization signals (PSS), secondary synchronization signals (SSS), synchronization signal blocks (SSBs), etc.) from a base station. The UE can then form a transmit beam for sending one or more uplink reference signals (e.g., uplink positioning reference signals (UL-PRS), sounding reference signal (SRS), demodulation reference signals (DMRS), PTRS, etc.) to that base station based on the parameters of the receive beam.

[0047] Note that a “downlink” beam may be either a transmit beam or a receive beam, depending on the entity forming it. For example, if a base station is forming the downlink beam to transmit a reference signal to a UE, the downlink beam is a transmit beam. If the UE is forming the downlink beam, however, it is a receive beam to receive the downlink reference signal. Similarly, an “uplink” beam may be either a transmit beam or a receive beam, depending on the entity forming it. For example, if a base station is forming the uplink beam, it is an uplink receive beam, and if a UE is forming the uplink beam, it is an uplink transmit beam.

[0048] In 5G, the frequency spectrum in which wireless nodes (e.g., base stations 102/180, UEs 104/182) operate is divided into multiple frequency ranges, FR1 (from 450 to 6000 MHz), FR2 (from 24250 to 52600 MHz), FR3 (above 52600 MHz), and FR4 (between FR1 and FR2). In a multi-carrier system, such as 5G, one of the carrier frequencies is referred to as the “primary carrier” or “anchor carrier” or “primary serving cell” or “PCell,” and the remaining carrier frequencies are referred to as “secondary carriers” or “secondary serving cells” or “SCells.” In carrier aggregation, the anchor carrier is the carrier operating on the primary frequency (e.g., FR1) utilized by a UE 104/182 and the cell in which the UE 104/182 either performs the initial radio resource control (RRC) connection establishment procedure or initiates the RRC connection re-establishment procedure. The primary carrier carries all common and UE-specific control channels, and may be a carrier in a licensed frequency (however, this is not always the case). A secondary carrier is a carrier operating on a second frequency (e.g., FR2) that may be configured once the RRC connection is established between the UE 104 and the anchor carrier and that may be used to provide additional radio resources. In some cases, the secondary carrier may be a carrier in an unlicensed frequency. The secondary carrier may contain only necessary signaling information and signals, for example, those that are UE-specific may not be present in the secondary carrier, since both primary uplink and downlink carriers are typically UE-specific. This means that different UEs 104/182 in a cell may have different downlink primary carriers. The same is true for the uplink primary carriers. The network is able to change the primary carrier of any UE 104/182 at any time. This is done, for example, to balance the load on different carriers. Because a “serving cell” (whether a PCell or an SCell) corresponds to a carrier frequency / component carrier over which some base station is communicating, the term “cell,” “serving cell,” “component carrier,” “carrier frequency,” and the like can be used interchangeably.

[0049] For example, still referring to FIG. 1, one of the frequencies utilized by the macro cell base stations 102 may be an anchor carrier (or “PCell”) and other frequencies utilized by the macro cell base stations 102 and/or the mmW base station 180 may be secondary carriers (“SCells”). The simultaneous transmission and/or reception of multiple carriers enables the UE 104/182 to significantly

increase its data transmission and/or reception rates. For example, two 20 MHz aggregated carriers in a multi-carrier system would theoretically lead to a two-fold increase in data rate (i.e., 40 MHz), compared to that attained by a single 20 MHz carrier.

[0050] The wireless communications system 100 may further include a UE 164 that may communicate with a macro cell base station 102 over a communication link 120 and/or the mmW base station 180 over a mmW communication link 184. For example, the macro cell base station 102 may support a PCell and one or more SCells for the UE 164 and the mmW base station 180 may support one or more SCells for the UE 164.

[0051] In the example of FIG. 1, one or more Earth orbiting satellite positioning system (SPS) space vehicles (SVs) 112 (e.g., satellites) may be used as an independent source of location information for any of the illustrated UEs (shown in FIG. 1 as a single UE 104 for simplicity). A UE 104 may include one or more dedicated SPS receivers specifically designed to receive SPS signals 124 for deriving geo location information from the SVs 112. An SPS typically includes a system of transmitters (e.g., SVs 112) positioned to enable receivers (e.g., UEs 104) to determine their location on or above the Earth based, at least in part, on signals (e.g., SPS signals 124) received from the transmitters. Such a transmitter typically transmits a signal marked with a repeating pseudo-random noise (PN) code of a set number of chips. While typically located in SVs 112, transmitters may sometimes be located on ground-based control stations, base stations 102, and/or other UEs 104.

[0052] The use of SPS signals 124 can be augmented by various satellite-based augmentation systems (SBAS) that may be associated with or otherwise enabled for use with one or more global and/or regional navigation satellite systems. For example an SBAS may include an augmentation system(s) that provides integrity information, differential corrections, etc., such as the Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay Service (EGNOS), the Multi-functional Satellite Augmentation System (MSAS), the Global Positioning System (GPS) Aided Geo Augmented Navigation or GPS and Geo Augmented Navigation system (GAGAN), and/or the like. Thus, as used herein, an SPS may include any combination of one or more global and/or regional

navigation satellite systems and/or augmentation systems, and SPS signals 124 may include SPS, SPS-like, and/or other signals associated with such one or more SPS.

[0053] The wireless communications system 100 may further include one or more UEs, such as UE 190, that connects indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links (referred to as “sidelinks”). In the example of FIG. 1, UE 190 has a D2D P2P link 192 with one of the UEs 104 connected to one of the base stations 102 (e.g., through which UE 190 may indirectly obtain cellular connectivity) and a D2D P2P link 194 with WLAN STA 152 connected to the WLAN AP 150 (through which UE 190 may indirectly obtain WLAN-based Internet connectivity). In an example, the D2D P2P links 192 and 194 may be supported with any well-known D2D RAT, such as LTE Direct (LTE-D), WiFi Direct (WiFi-D), Bluetooth®, and so on.

[0054] FIG. 2A illustrates an example wireless network structure 200. For example, a 5GC 210 (also referred to as a Next Generation Core (NGC)) can be viewed functionally as control plane functions 214 (e.g., UE registration, authentication, network access, gateway selection, etc.) and user plane functions 212, (e.g., UE gateway function, access to data networks, IP routing, etc.) which operate cooperatively to form the core network. User plane interface (NG-U) 213 and control plane interface (NG-C) 215 connect the gNB 222 to the 5GC 210 and specifically to the control plane functions 214 and user plane functions 212. In an additional configuration, an ng-eNB 224 may also be connected to the 5GC 210 via NG-C 215 to the control plane functions 214 and NG-U 213 to user plane functions 212. Further, ng-eNB 224 may directly communicate with gNB 222 via a backhaul connection 223. In some configurations, a Next Generation RAN (NG-RAN) 220 may only have one or more gNBs 222, while other configurations include one or more of both ng-eNBs 224 and gNBs 222. Either gNB 222 or ng-eNB 224 may communicate with UEs 204 (e.g., any of the UEs depicted in FIG. 1). Another optional aspect may include location server 230, which may be in communication with the 5GC 210 to provide location assistance for UEs 204. The location server 230 can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server,

different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The location server 230 can be configured to support one or more location services for UEs 204 that can connect to the location server 230 via the core network, 5GC 210, and/or via the Internet (not illustrated). Further, the location server 230 may be integrated into a component of the core network, or alternatively may be external to the core network.

[0055] FIG. 2B illustrates another example wireless network structure 250. A 5GC 260 (which may correspond to 5GC 210 in FIG. 2A) can be viewed functionally as control plane functions, provided by an access and mobility management function (AMF) 264, and user plane functions, provided by a user plane function (UPF) 262, which operate cooperatively to form the core network (i.e., 5GC 260). User plane interface 263 and control plane interface 265 connect the ng-eNB 224 to the 5GC 260 and specifically to UPF 262 and AMF 264, respectively. In an additional configuration, a gNB 222 may also be connected to the 5GC 260 via control plane interface 265 to AMF 264 and user plane interface 263 to UPF 262. Further, ng-eNB 224 may directly communicate with gNB 222 via the backhaul connection 223, with or without gNB direct connectivity to the 5GC 260. In some configurations, the NG-RAN 220 may only have one or more gNBs 222, while other configurations include one or more of both ng-eNBs 224 and gNBs 222. Either gNB 222 or ng-eNB 224 may communicate with UEs 204 (e.g., any of the UEs depicted in FIG. 1). The base stations of the NG-RAN 220 communicate with the AMF 264 over the N2 interface and with the UPF 262 over the N3 interface.

[0056] The functions of the AMF 264 include registration management, connection management, reachability management, mobility management, lawful interception, transport for session management (SM) messages between the UE 204 and a session management function (SMF) 266, transparent proxy services for routing SM messages, access authentication and access authorization, transport for short message service (SMS) messages between the UE 204 and the short message service function (SMSF) (not shown), and security anchor functionality (SEAF). The AMF 264 also interacts with an authentication server function (AUSF) (not shown) and the UE 204, and receives the intermediate key

that was established as a result of the UE 204 authentication process. In the case of authentication based on a UMTS (universal mobile telecommunications system) subscriber identity module (USIM), the AMF 264 retrieves the security material from the AUSF. The functions of the AMF 264 also include security context management (SCM). The SCM receives a key from the SEAF that it uses to derive access-network specific keys. The functionality of the AMF 264 also includes location services management for regulatory services, transport for location services messages between the UE 204 and an LMF 270 (which acts as a location server 230), transport for location services messages between the NG-RAN 220 and the LMF 270, evolved packet system (EPS) bearer identifier allocation for interworking with the EPS, and UE 204 mobility event notification. In addition, the AMF 264 also supports functionalities for non-3GPP (Third Generation Partnership Project) access networks.

[0057] Functions of the UPF 262 include acting as an anchor point for intra-/inter-RAT mobility (when applicable), acting as an external protocol data unit (PDU) session point of interconnect to a data network (not shown), providing packet routing and forwarding, packet inspection, user plane policy rule enforcement (e.g., gating, redirection, traffic steering), lawful interception (user plane collection), traffic usage reporting, quality of service (QoS) handling for the user plane (e.g., uplink/ downlink rate enforcement, reflective QoS marking in the downlink), uplink traffic verification (service data flow (SDF) to QoS flow mapping), transport level packet marking in the uplink and downlink, downlink packet buffering and downlink data notification triggering, and sending and forwarding of one or more “end markers” to the source RAN node. The UPF 262 may also support transfer of location services messages over a user plane between the UE 204 and a location server, such as an SLP 272.

[0058] The functions of the SMF 266 include session management, UE Internet protocol (IP) address allocation and management, selection and control of user plane functions, configuration of traffic steering at the UPF 262 to route traffic to the proper destination, control of part of policy enforcement and QoS, and downlink data notification. The interface over which the SMF 266 communicates with the AMF 264 is referred to as the N11 interface.

[0059] Another optional aspect may include an LMF 270, which may be in communication with the 5GC 260 to provide location assistance for UEs 204. The LMF 270 can be implemented as a plurality of separate servers (e.g., physically separate servers, different software modules on a single server, different software modules spread across multiple physical servers, etc.), or alternately may each correspond to a single server. The LMF 270 can be configured to support one or more location services for UEs 204 that can connect to the LMF 270 via the core network, 5GC 260, and/or via the Internet (not illustrated). The SLP 272 may support similar functions to the LMF 270, but whereas the LMF 270 may communicate with the AMF 264, NG-RAN 220, and UEs 204 over a control plane (e.g., using interfaces and protocols intended to convey signaling messages and not voice or data), the SLP 272 may communicate with UEs 204 and external clients (not shown in FIG. 2B) over a user plane (e.g., using protocols intended to carry voice and/or data like the transmission control protocol (TCP) and/or IP).

[0060] FIGS. 3A, 3B, and 3C illustrate several example components (represented by corresponding blocks) that may be incorporated into a UE 302 (which may correspond to any of the UEs described herein), a base station 304 (which may correspond to any of the base stations described herein), and a network entity 306 (which may correspond to or embody any of the network functions described herein, including the location server 230 and the LMF 270) to support the file transmission operations as taught herein. It will be appreciated that these components may be implemented in different types of apparatuses in different implementations (e.g., in an ASIC, in a system-on-chip (SoC), etc.). The illustrated components may also be incorporated into other apparatuses in a communication system. For example, other apparatuses in a system may include components similar to those described to provide similar functionality. Also, a given apparatus may contain one or more of the components. For example, an apparatus may include multiple transceiver components that enable the apparatus to operate on multiple carriers and/or communicate via different technologies.

[0061] The UE 302 and the base station 304 each include wireless wide area network (WWAN) transceiver 310 and 350, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) via one

or more wireless communication networks (not shown), such as an NR network, an LTE network, a GSM network, and/or the like. The WWAN transceivers 310 and 350 may be connected to one or more antennas 316 and 356, respectively, for communicating with other network nodes, such as other UEs, access points, base stations (e.g., eNBs, gNBs), etc., via at least one designated RAT (e.g., NR, LTE, GSM, etc.) over a wireless communication medium of interest (e.g., some set of time/frequency resources in a particular frequency spectrum). The WWAN transceivers 310 and 350 may be variously configured for transmitting and encoding signals 318 and 358 (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals 318 and 358 (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the WWAN transceivers 310 and 350 include one or more transmitters 314 and 354, respectively, for transmitting and encoding signals 318 and 358, respectively, and one or more receivers 312 and 352, respectively, for receiving and decoding signals 318 and 358, respectively.

[0062] The UE 302 and the base station 304 also include, at least in some cases, one or more short-range wireless transceivers 320 and 360, respectively. The short-range wireless transceivers 320 and 360 may be connected to one or more antennas 326 and 366, respectively, and provide means for communicating (e.g., means for transmitting, means for receiving, means for measuring, means for tuning, means for refraining from transmitting, etc.) with other network nodes, such as other UEs, access points, base stations, etc., via at least one designated RAT (e.g., WiFi, LTE-D, Bluetooth®, Zigbee®, Z-Wave®, PC5, dedicated short-range communications (DSRC), wireless access for vehicular environments (WAVE), near-field communication (NFC), etc.) over a wireless communication medium of interest. The short-range wireless transceivers 320 and 360 may be variously configured for transmitting and encoding signals 328 and 368 (e.g., messages, indications, information, and so on), respectively, and, conversely, for receiving and decoding signals 328 and 368 (e.g., messages, indications, information, pilots, and so on), respectively, in accordance with the designated RAT. Specifically, the short-range wireless transceivers 320 and 360 include one or more transmitters 324 and 364, respectively, for transmitting and encoding

signals 328 and 368, respectively, and one or more receivers 322 and 362, respectively, for receiving and decoding signals 328 and 368, respectively. As specific examples, the short-range wireless transceivers 320 and 360 may be WiFi transceivers, Bluetooth® transceivers, Zigbee® and/or Z-Wave® transceivers, NFC transceivers, or vehicle-to-vehicle (V2V) and/or vehicle-to-everything (V2X) transceivers.

[0063] Transceiver circuitry including at least one transmitter and at least one receiver may comprise an integrated device (e.g., embodied as a transmitter circuit and a receiver circuit of a single communication device) in some implementations, may comprise a separate transmitter device and a separate receiver device in some implementations, or may be embodied in other ways in other implementations. In an aspect, a transmitter may include or be coupled to a plurality of antennas (e.g., antennas 316, 326, 356, 366), such as an antenna array, that permits the respective apparatus to perform transmit “beamforming,” as described herein. Similarly, a receiver may include or be coupled to a plurality of antennas (e.g., antennas 316, 326, 356, 366), such as an antenna array, that permits the respective apparatus to perform receive beamforming, as described herein. In an aspect, the transmitter and receiver may share the same plurality of antennas (e.g., antennas 316, 326, 356, 366), such that the respective apparatus can only receive or transmit at a given time, not both at the same time. A wireless communication device (e.g., one or both of the transceivers 310 and 320 and/or 350 and 360) of the UE 302 and/or the base station 304 may also comprise a network listen module (NLM) or the like for performing various measurements.

[0064] The UE 302 and the base station 304 also include, at least in some cases, satellite positioning systems (SPS) receivers 330 and 370. The SPS receivers 330 and 370 may be connected to one or more antennas 336 and 376, respectively, and may provide means for receiving and/or measuring SPS signals 338 and 378, respectively, such as global positioning system (GPS) signals, global navigation satellite system (GLONASS) signals, Galileo signals, Beidou signals, Indian Regional Navigation Satellite System (NAVIC), Quasi-Zenith Satellite System (QZSS), etc. The SPS receivers 330 and 370 may comprise any suitable hardware and/or software for receiving and processing SPS signals 338 and 378, respectively. The SPS receivers 330 and 370 request information and operations

as appropriate from the other systems, and performs calculations necessary to determine positions of the UE 302 and the base station 304 using measurements obtained by any suitable SPS algorithm.

[0065] The base station 304 and the network entity 306 each include at least one network interfaces 380 and 390, respectively, providing means for communicating (e.g., means for transmitting, means for receiving, etc.) with other network entities. For example, the network interfaces 380 and 390 (e.g., one or more network access ports) may be configured to communicate with one or more network entities via a wire-based or wireless backhaul connection. In some aspects, the network interfaces 380 and 390 may be implemented as transceivers configured to support wire-based or wireless signal communication. This communication may involve, for example, sending and receiving messages, parameters, and/or other types of information.

[0066] The UE 302, the base station 304, and the network entity 306 also include other components that may be used in conjunction with the operations as disclosed herein. The UE 302 includes processor circuitry implementing a processing system 332 for providing functionality relating to, for example, wireless positioning, and for providing other processing functionality. The base station 304 includes a processing system 384 for providing functionality relating to, for example, wireless positioning as disclosed herein, and for providing other processing functionality. The network entity 306 includes a processing system 394 for providing functionality relating to, for example, wireless positioning as disclosed herein, and for providing other processing functionality. The processing systems 332, 384, and 394 may therefore provide means for processing, such as means for determining, means for calculating, means for receiving, means for transmitting, means for indicating, etc. In an aspect, the processing systems 332, 384, and 394 may include, for example, one or more processors, such as one or more general purpose processors, multi-core processors, ASICs, digital signal processors (DSPs), field programmable gate arrays (FPGA), other programmable logic devices or processing circuitry, or various combinations thereof.

[0067] The UE 302, the base station 304, and the network entity 306 include memory circuitry implementing memory components 340, 386, and 396 (e.g., each including a memory device), respectively, for maintaining information (e.g.,

information indicative of reserved resources, thresholds, parameters, and so on). The memory components 340, 386, and 396 may therefore provide means for storing, means for retrieving, means for maintaining, etc. In some cases, the UE 302, the base station 304, and the network entity 306 may include RIS modules 342, 388, and 398, respectively. The RIS modules 342, 388, and 398 may be hardware circuits that are part of or coupled to the processing systems 332, 384, and 394, respectively, that, when executed, cause the UE 302, the base station 304, and the network entity 306 to perform the functionality described herein. In other aspects, the RIS modules 342, 388, and 398 may be external to the processing systems 332, 384, and 394 (e.g., part of a modem processing system, integrated with another processing system, etc.). Alternatively, the RIS modules 342, 388, and 398 may be memory modules stored in the memory components 340, 386, and 396, respectively, that, when executed by the processing systems 332, 384, and 394 (or a modem processing system, another processing system, etc.), cause the UE 302, the base station 304, and the network entity 306 to perform the functionality described herein. FIG. 3A illustrates possible locations of the RIS module 342, which may be part of the WWAN transceiver 310, the memory component 340, the processing system 332, or any combination thereof, or may be a standalone component. FIG. 3B illustrates possible locations of the RIS module 388, which may be part of the WWAN transceiver 350, the memory component 386, the processing system 384, or any combination thereof, or may be a standalone component. FIG. 3C illustrates possible locations of the RIS module 398, which may be part of the network interface(s) 390, the memory component 396, the processing system 394, or any combination thereof, or may be a standalone component.

[0068] The UE 302 may include one or more sensors 344 coupled to the processing system 332 to provide means for sensing or detecting movement and/or orientation information that is independent of motion data derived from signals received by the WWAN transceiver 310, the short-range wireless transceiver 320, and/or the SPS receiver 330. By way of example, the sensor(s) 344 may include an accelerometer (e.g., a micro-electrical mechanical systems (MEMS) device), a gyroscope, a geomagnetic sensor (e.g., a compass), an altimeter (e.g., a barometric pressure altimeter), and/or any other type of movement detection sensor.

Moreover, the sensor(s) 344 may include a plurality of different types of devices and combine their outputs in order to provide motion information. For example, the sensor(s) 344 may use a combination of a multi-axis accelerometer and orientation sensors to provide the ability to compute positions in 2D and/or 3D coordinate systems.

[0069] In addition, the UE 302 includes a user interface 346 providing means for providing indications (e.g., audible and/or visual indications) to a user and/or for receiving user input (e.g., upon user actuation of a sensing device such a keypad, a touch screen, a microphone, and so on). Although not shown, the base station 304 and the network entity 306 may also include user interfaces.

[0070] Referring to the processing system 384 in more detail, in the downlink, IP packets from the network entity 306 may be provided to the processing system 384. The processing system 384 may implement functionality for an RRC layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The processing system 384 may provide RRC layer functionality associated with broadcasting of system information (e.g., master information block (MIB), system information blocks (SIBs)), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter-RAT mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression/decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer PDUs, error correction through automatic repeat request (ARQ), concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, scheduling information reporting, error correction, priority handling, and logical channel prioritization.

[0071] The transmitter 354 and the receiver 352 may implement Layer-1 (L1) functionality associated with various signal processing functions. Layer-1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport

channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The transmitter 354 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an orthogonal frequency division multiplexing (OFDM) subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an inverse fast Fourier transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM symbol stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 302. Each spatial stream may then be provided to one or more different antennas 356. The transmitter 354 may modulate an RF carrier with a respective spatial stream for transmission.

[0072] At the UE 302, the receiver 312 receives a signal through its respective antenna(s) 316. The receiver 312 recovers information modulated onto an RF carrier and provides the information to the processing system 332. The transmitter 314 and the receiver 312 implement Layer-1 functionality associated with various signal processing functions. The receiver 312 may perform spatial processing on the information to recover any spatial streams destined for the UE 302. If multiple spatial streams are destined for the UE 302, they may be combined by the receiver 312 into a single OFDM symbol stream. The receiver 312 then converts the OFDM symbol stream from the time-domain to the frequency domain using a fast Fourier transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 304. These soft decisions may be based on channel estimates computed by a channel estimator. The soft decisions are then decoded and de-interleaved to

recover the data and control signals that were originally transmitted by the base station 304 on the physical channel. The data and control signals are then provided to the processing system 332, which implements Layer-3 (L3) and Layer-2 (L2) functionality.

[0073] In the uplink, the processing system 332 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the core network. The processing system 332 is also responsible for error detection.

[0074] Similar to the functionality described in connection with the downlink transmission by the base station 304, the processing system 332 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through hybrid automatic repeat request (HARQ), priority handling, and logical channel prioritization.

[0075] Channel estimates derived by the channel estimator from a reference signal or feedback transmitted by the base station 304 may be used by the transmitter 314 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the transmitter 314 may be provided to different antenna(s) 316. The transmitter 314 may modulate an RF carrier with a respective spatial stream for transmission.

[0076] The uplink transmission is processed at the base station 304 in a manner similar to that described in connection with the receiver function at the UE 302. The receiver 352 receives a signal through its respective antenna(s) 356. The receiver 352 recovers information modulated onto an RF carrier and provides the information to the processing system 384.

[0077] In the uplink, the processing system 384 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 302. IP packets from the processing system 384 may be provided to the core network. The processing system 384 is also responsible for error detection.

[0078] For convenience, the UE 302, the base station 304, and/or the network entity 306 are shown in FIGS. 3A to 3C as including various components that may be configured according to the various examples described herein. It will be appreciated, however, that the illustrated blocks may have different functionality in different designs.

[0079] The various components of the UE 302, the base station 304, and the network entity 306 may communicate with each other over data buses 334, 382, and 392, respectively. The components of FIGS. 3A to 3C may be implemented in various ways. In some implementations, the components of FIGS. 3A to 3C may be implemented in one or more circuits such as, for example, one or more processors and/or one or more ASICs (which may include one or more processors). Here, each circuit may use and/or incorporate at least one memory component for storing information or executable code used by the circuit to provide this functionality. For example, some or all of the functionality represented by blocks 310 to 346 may be implemented by processor and memory component(s) of the UE 302 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Similarly, some or all of the functionality represented by blocks 350 to 388 may be implemented by processor and memory component(s) of the base station 304 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). Also, some or all of the functionality represented by blocks 390 to 398 may be implemented by processor and memory component(s) of the network entity 306 (e.g., by execution of appropriate code and/or by appropriate configuration of processor components). For simplicity, various operations, acts, and/or functions are described herein as being performed “by a UE,” “by a base station,” “by a network entity,” etc. However, as will be appreciated, such operations, acts, and/or functions may actually be performed by specific components or combinations of components of the UE 302, base station 304, network entity 306,

etc., such as the processing systems 332, 384, 394, the transceivers 310, 320, 350, and 360, the memory components 340, 386, and 396, the RIS modules 342, 388, and 398, etc.

[0080] Various frame structures may be used to support downlink and uplink transmissions between network nodes (e.g., base stations and UEs). FIG. 4A is a diagram 400 illustrating an example of a downlink frame structure, according to aspects of the disclosure. FIG. 4B is a diagram 430 illustrating an example of channels within the downlink frame structure, according to aspects of the disclosure. FIG. 4C is a diagram 450 illustrating an example of an uplink frame structure, according to aspects of the disclosure. FIG. 4D is a diagram 480 illustrating an example of channels within an uplink frame structure, according to aspects of the disclosure. Other wireless communications technologies may have different frame structures and/or different channels.

[0081] LTE, and in some cases NR, utilizes OFDM on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. Unlike LTE, however, NR has an option to use OFDM on the uplink as well. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kilohertz (kHz) and the minimum resource allocation (resource block) may be 12 subcarriers (or 180 kHz). Consequently, the nominal FFT size may be equal to 128, 256, 512, 1024, or 2048 for system bandwidth of 1.25, 2.5, 5, 10, or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.08 MHz (i.e., 6 resource blocks), and there may be 1, 2, 4, 8, or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10, or 20 MHz, respectively.

[0082] LTE supports a single numerology (subcarrier spacing (SCS), symbol length, etc.). In contrast, NR may support multiple numerologies (μ), for example, subcarrier spacings of 15 kHz ($\mu=0$), 30 kHz ($\mu=1$), 60 kHz ($\mu=2$), 120 kHz ($\mu=3$), and 240 kHz ($\mu=4$) or greater may be available. In each subcarrier spacing, there

are 14 symbols per slot. For 15 kHz SCS ($\mu=0$), there is one slot per subframe, 10 slots per frame, the slot duration is 1 millisecond (ms), the symbol duration is 66.7 microseconds (μs), and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 50. For 30 kHz SCS ($\mu=1$), there are two slots per subframe, 20 slots per frame, the slot duration is 0.5 ms, the symbol duration is 33.3 μs , and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 100. For 60 kHz SCS ($\mu=2$), there are four slots per subframe, 40 slots per frame, the slot duration is 0.25 ms, the symbol duration is 16.7 μs , and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 200. For 120 kHz SCS ($\mu=3$), there are eight slots per subframe, 80 slots per frame, the slot duration is 0.125 ms, the symbol duration is 8.33 μs , and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 400. For 240 kHz SCS ($\mu=4$), there are 16 slots per subframe, 160 slots per frame, the slot duration is 0.0625 ms, the symbol duration is 4.17 μs , and the maximum nominal system bandwidth (in MHz) with a 4K FFT size is 800.

[0083] In the example of FIGS. 4A to 4D, a numerology of 15 kHz is used. Thus, in the time domain, a 10 ms frame is divided into 10 equally sized subframes of 1 ms each, and each subframe includes one time slot. In FIGS. 4A to 4D, time is represented horizontally (on the X axis) with time increasing from left to right, while frequency is represented vertically (on the Y axis) with frequency increasing (or decreasing) from bottom to top.

[0084] A resource grid may be used to represent time slots, each time slot including one or more time-concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)) in the frequency domain. The resource grid is further divided into multiple resource elements (REs). An RE may correspond to one symbol length in the time domain and one subcarrier in the frequency domain. In the numerology of FIGS. 4A to 4D, for a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and seven consecutive symbols in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and six consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.

[0085] Some of the REs carry downlink reference (pilot) signals (DL-RS). The DL-RS may include PRS, TRS, PTRS, CRS, CSI-RS, DMRS, PSS, SSS, SSB, etc. FIG. 4A illustrates example locations of REs carrying PRS (labeled “R”).

[0086] A collection of resource elements (REs) that are used for transmission of PRS is referred to as a “PRS resource.” The collection of resource elements can span multiple PRBs in the frequency domain and ‘N’ (such as 1 or more) consecutive symbol(s) within a slot in the time domain. In a given OFDM symbol in the time domain, a PRS resource occupies consecutive PRBs in the frequency domain.

[0087] The transmission of a PRS resource within a given PRB has a particular comb size (also referred to as the “comb density”). A comb size ‘N’ represents the subcarrier spacing (or frequency/tone spacing) within each symbol of a PRS resource configuration. Specifically, for a comb size ‘N,’ PRS are transmitted in every Nth subcarrier of a symbol of a PRB. For example, for comb-4, for each symbol of the PRS resource configuration, REs corresponding to every fourth subcarrier (such as subcarriers 0, 4, 8) are used to transmit PRS of the PRS resource. Currently, comb sizes of comb-2, comb-4, comb-6, and comb-12 are supported for DL-PRS. FIG. 4A illustrates an example PRS resource configuration for comb-6 (which spans six symbols). That is, the locations of the shaded REs (labeled “R”) indicate a comb-6 PRS resource configuration.

[0088] Currently, a DL-PRS resource may span 2, 4, 6, or 12 consecutive symbols within a slot with a fully frequency-domain staggered pattern. A DL-PRS resource can be configured in any higher layer configured downlink or flexible (FL) symbol of a slot. There may be a constant energy per resource element (EPRE) for all REs of a given DL-PRS resource. The following are the frequency offsets from symbol to symbol for comb sizes 2, 4, 6, and 12 over 2, 4, 6, and 12 symbols. 2-symbol comb-2: {0, 1}; 4-symbol comb-2: {0, 1, 0, 1}; 6-symbol comb-2: {0, 1, 0, 1, 0, 1}; 12-symbol comb-2: {0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}; 4-symbol comb-4: {0, 2, 1, 3}; 12-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3}; 6-symbol comb-6: {0, 3, 1, 4, 2, 5}; 12-symbol comb-6: {0, 3, 1, 4, 2, 5, 0, 3, 1, 4, 2, 5}; and 12-symbol comb-12: {0, 6, 3, 9, 1, 7, 4, 10, 2, 8, 5, 11}.

[0089] A “PRS resource set” is a set of PRS resources used for the transmission of PRS signals, where each PRS resource has a PRS resource ID. In addition, the

PRS resources in a PRS resource set are associated with the same TRP. A PRS resource set is identified by a PRS resource set ID and is associated with a particular TRP (identified by a TRP ID). In addition, the PRS resources in a PRS resource set have the same periodicity, a common muting pattern configuration, and the same repetition factor (such as “PRS-ResourceRepetitionFactor”) across slots. The periodicity is the time from the first repetition of the first PRS resource of a first PRS instance to the same first repetition of the same first PRS resource of the next PRS instance. The periodicity may have a length selected from $2^{\mu} \cdot \{4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 160, 320, 640, 1280, 2560, 5120, 10240\}$ slots, with $\mu = 0, 1, 2, 3$. The repetition factor may have a length selected from $\{1, 2, 4, 6, 8, 16, 32\}$ slots.

[0090] A PRS resource ID in a PRS resource set is associated with a single beam (or beam ID) transmitted from a single TRP (where a TRP may transmit one or more beams). That is, each PRS resource of a PRS resource set may be transmitted on a different beam, and as such, a “PRS resource,” or simply “resource,” also can be referred to as a “beam.” Note that this does not have any implications on whether the TRPs and the beams on which PRS are transmitted are known to the UE.

[0091] A “PRS instance” or “PRS occasion” is one instance of a periodically repeated time window (such as a group of one or more consecutive slots) where PRS are expected to be transmitted. A PRS occasion also may be referred to as a “PRS positioning occasion,” a “PRS positioning instance,” a “positioning occasion,” “a positioning instance,” a “positioning repetition,” or simply an “occasion,” an “instance,” or a “repetition.”

[0092] A “positioning frequency layer” (also referred to simply as a “frequency layer”) is a collection of one or more PRS resource sets across one or more TRPs that have the same values for certain parameters. Specifically, the collection of PRS resource sets has the same subcarrier spacing and cyclic prefix (CP) type (meaning all numerologies supported for the PDSCH are also supported for PRS), the same Point A, the same value of the downlink PRS bandwidth, the same start PRB (and center frequency), and the same comb-size. The Point A parameter takes the value of the parameter “ARFCN-ValueNR” (where “ARFCN” stands for “absolute radio-frequency channel number”) and is an identifier/code that

specifies a pair of physical radio channel used for transmission and reception. The downlink PRS bandwidth may have a granularity of four PRBs, with a minimum of 24 PRBs and a maximum of 272 PRBs. Currently, up to four frequency layers have been defined, and up to two PRS resource sets may be configured per TRP per frequency layer.

[0093] The concept of a frequency layer is somewhat like the concept of component carriers and bandwidth parts (BWPs), but different in that component carriers and BWPs are used by one base station (or a macro cell base station and a small cell base station) to transmit data channels, while frequency layers are used by several (usually three or more) base stations to transmit PRS. A UE may indicate the number of frequency layers it can support when it sends the network its positioning capabilities, such as during an LTE positioning protocol (LPP) session. For example, a UE may indicate whether it can support one or four positioning frequency layers.

[0094] FIG. 4B illustrates an example of various channels within a downlink slot of a radio frame. In NR, the channel bandwidth, or system bandwidth, is divided into multiple BWPs. A BWP is a contiguous set of PRBs selected from a contiguous subset of the common RBs for a given numerology on a given carrier. Generally, a maximum of four BWPs can be specified in the downlink and uplink. That is, a UE can be configured with up to four BWPs on the downlink, and up to four BWPs on the uplink. Only one BWP (uplink or downlink) may be active at a given time, meaning the UE may only receive or transmit over one BWP at a time. On the downlink, the bandwidth of each BWP should be equal to or greater than the bandwidth of the SSB, but it may or may not contain the SSB.

[0095] Referring to FIG. 4B, a primary synchronization signal (PSS) is used by a UE to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a PCI. Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH), which carries an MIB, may be logically grouped with the PSS and SSS to form an SSB (also referred to as an SS/PBCH). The MIB provides a number of RBs in the downlink

system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH, such as system information blocks (SIBs), and paging messages.

[0096] The physical downlink control channel (PDCCH) carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including one or more RE group (REG) bundles (which may span multiple symbols in the time domain), each REG bundle including one or more REGs, each REG corresponding to 12 resource elements (one resource block) in the frequency domain and one OFDM symbol in the time domain. The set of physical resources used to carry the PDCCH/DCI is referred to in NR as the control resource set (CORESET). In NR, a PDCCH is confined to a single CORESET and is transmitted with its own DMRS. This enables UE-specific beamforming for the PDCCH.

[0097] In the example of FIG. 4B, there is one CORESET per BWP, and the CORESET spans three symbols (although it may be only one or two symbols) in the time domain. Unlike LTE control channels, which occupy the entire system bandwidth, in NR, PDCCH channels are localized to a specific region in the frequency domain (i.e., a CORESET). Thus, the frequency component of the PDCCH shown in FIG. 4B is illustrated as less than a single BWP in the frequency domain. Note that although the illustrated CORESET is contiguous in the frequency domain, it need not be. In addition, the CORESET may span less than three symbols in the time domain.

[0098] The DCI within the PDCCH carries information about uplink resource allocation (persistent and non-persistent) and descriptions about downlink data transmitted to the UE, referred to as uplink and downlink grants, respectively. More specifically, the DCI indicates the resources scheduled for the downlink data channel (e.g., PDSCH) and the uplink data channel (e.g., PUSCH). Multiple (e.g., up to eight) DCIs can be configured in the PDCCH, and these DCIs can have one of multiple formats. For example, there are different DCI formats for uplink scheduling, for downlink scheduling, for uplink transmit power control (TPC), etc. A PDCCH may be transported by 1, 2, 4, 8, or 16 CCEs in order to accommodate different DCI payload sizes or coding rates.

[0099] As illustrated in FIG. 4C, some of the REs (labeled “R”) carry DMRS for channel estimation at the receiver (e.g., a base station, another UE, etc.). A UE may additionally transmit SRS in, for example, the last symbol of a slot. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. In the example of FIG. 4C, the illustrated SRS is comb-2 over one symbol. The SRS may be used by a base station to obtain the channel state information (CSI) for each UE. CSI describes how an RF signal propagates from the UE to the base station and represents the combined effect of scattering, fading, and power decay with distance. The system uses the SRS for resource scheduling, link adaptation, massive MIMO, beam management, etc.

[0100] Currently, an SRS resource may span 1, 2, 4, 8, or 12 consecutive symbols within a slot with a comb size of comb-2, comb-4, or comb-8. The following are the frequency offsets from symbol to symbol for the SRS comb patterns that are currently supported. 1-symbol comb-2: {0}; 2-symbol comb-2: {0, 1}; 4-symbol comb-2: {0, 1, 0, 1}; 4-symbol comb-4: {0, 2, 1, 3}; 8-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3}; 12-symbol comb-4: {0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3}; 4-symbol comb-8: {0, 4, 2, 6}; 8-symbol comb-8: {0, 4, 2, 6, 1, 5, 3, 7}; and 12-symbol comb-8: {0, 4, 2, 6, 1, 5, 3, 7, 0, 4, 2, 6}.

[0101] A collection of resource elements that are used for transmission of SRS is referred to as an “SRS resource,” and may be identified by the parameter “SRS-ResourceId.” The collection of resource elements can span multiple PRBs in the frequency domain and N (e.g., one or more) consecutive symbol(s) within a slot in the time domain. In a given OFDM symbol, an SRS resource occupies consecutive PRBs. An “SRS resource set” is a set of SRS resources used for the transmission of SRS signals, and is identified by an SRS resource set ID (“SRS-ResourceSetId”).

[0102] Generally, a UE transmits SRS to enable the receiving base station (either the serving base station or a neighboring base station) to measure the channel quality between the UE and the base station. However, SRS can also be specifically configured as uplink positioning reference signals for uplink-based positioning procedures, such as uplink time difference of arrival (UL-TDOA), round-trip-time (RTT), uplink angle-of-arrival (UL-AoA), etc. As used herein, the term “SRS” may refer to SRS configured for channel quality measurements or

SRS configured for positioning purposes. The former may be referred to herein as “SRS-for-communication” and/or the latter may be referred to as “SRS-for-positioning” when needed to distinguish the two types of SRS.

[0103] Several enhancements over the previous definition of SRS have been proposed for SRS-for-positioning (also referred to as “UL-PRS”), such as a new staggered pattern within an SRS resource (except for single-symbol/comb-2), a new comb type for SRS, new sequences for SRS, a higher number of SRS resource sets per component carrier, and a higher number of SRS resources per component carrier. In addition, the parameters “SpatialRelationInfo” and “PathLossReference” are to be configured based on a downlink reference signal or SSB from a neighboring TRP. Further still, one SRS resource may be transmitted outside the active BWP, and one SRS resource may span across multiple component carriers. Also, SRS may be configured in RRC connected state and only transmitted within an active BWP. Further, there may be no frequency hopping, no repetition factor, a single antenna port, and new lengths for SRS (e.g., 8 and 12 symbols). There also may be open-loop power control and not closed-loop power control, and comb-8 (i.e., an SRS transmitted every eighth subcarrier in the same symbol) may be used. Lastly, the UE may transmit through the same transmit beam from multiple SRS resources for UL-AoA. All of these are features that are additional to the current SRS framework, which is configured through RRC higher layer signaling (and potentially triggered or activated through MAC control element (CE) or DCI).

[0104] FIG. 4D illustrates an example of various channels within an uplink slot of a frame, according to aspects of the disclosure. A random-access channel (RACH), also referred to as a physical random-access channel (PRACH), may be within one or more slots within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a slot. The PRACH allows the UE to perform initial system access and achieve uplink synchronization. A physical uplink control channel (PUCCH) may be located on edges of the uplink system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, CSI reports, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The physical uplink shared channel (PUSCH) carries data, and may additionally

be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

[0105] Note that the terms “positioning reference signal” and “PRS” generally refer to specific reference signals that are used for positioning in NR and LTE systems. However, as used herein, the terms “positioning reference signal” and “PRS” may also refer to any type of reference signal that can be used for positioning, such as but not limited to, PRS as defined in LTE and NR, TRS, PTRS, CRS, CSI-RS, DMRS, PSS, SSS, SSB, SRS, UL-PRS, etc. In addition, the terms “positioning reference signal” and “PRS” may refer to downlink or uplink positioning reference signals, unless otherwise indicated by the context. If needed to further distinguish the type of PRS, a downlink positioning reference signal may be referred to as a “DL-PRS,” and an uplink positioning reference signal (e.g., an SRS-for-positioning, PTRS) may be referred to as an “UL-PRS.” In addition, for signals that may be transmitted in both the uplink and downlink (e.g., DMRS, PTRS), the signals may be prepended with “UL” or “DL” to distinguish the direction. For example, “UL-DMRS” may be differentiated from “DL-DMRS.”

[0106] NR supports a number of cellular network-based positioning technologies, including downlink-based, uplink-based, and downlink-and-uplink-based positioning methods. Downlink-based positioning methods include observed time difference of arrival (OTDOA) in LTE, downlink time difference of arrival (DL-TDOA) in NR, and downlink angle-of-departure (DL-AoD) in NR. In an OTDOA or DL-TDOA positioning procedure, a UE measures the differences between the times of arrival (ToAs) of reference signals (e.g., PRS, TRS, CSI-RS, SSB, etc.) received from pairs of base stations, referred to as reference signal time difference (RSTD) or time difference of arrival (TDOA) measurements, and reports them to a positioning entity. More specifically, the UE receives the identifiers (IDs) of a reference base station (e.g., a serving base station) and multiple non-reference base stations in assistance data. The UE then measures the RSTD between the reference base station and each of the non-reference base stations. Based on the known locations of the involved base stations and the RSTD measurements, the positioning entity can estimate the UE's location.

[0107] For DL-AoD positioning, the positioning entity uses a beam report from the UE of received signal strength measurements of multiple downlink transmit beams to determine the angle(s) between the UE and the transmitting base station(s). The positioning entity can then estimate the location of the UE based on the determined angle(s) and the known location(s) of the transmitting base station(s).

[0108] Uplink-based positioning methods include uplink time difference of arrival (UL-TDOA) and uplink angle-of-arrival (UL-AoA). UL-TDOA is similar to DL-TDOA, but is based on uplink reference signals (e.g., SRS) transmitted by the UE. For UL-AoA positioning, one or more base stations measure the received signal strength of one or more uplink reference signals (e.g., SRS) received from a UE on one or more uplink receive beams. The positioning entity uses the signal strength measurements and the angle(s) of the receive beam(s) to determine the angle(s) between the UE and the base station(s). Based on the determined angle(s) and the known location(s) of the base station(s), the positioning entity can then estimate the location of the UE.

[0109] Downlink-and-uplink-based positioning methods include enhanced cell-ID (E-CID) positioning and multi-round-trip-time (RTT) positioning (also referred to as “multi-cell RTT”). In an RTT procedure, an initiator (a base station or a UE) transmits an RTT measurement signal (e.g., a PRS or SRS) to a responder (a UE or base station), which transmits an RTT response signal (e.g., an SRS or PRS) back to the initiator. The RTT response signal includes the difference between the ToA of the RTT measurement signal and the transmission time of the RTT response signal, referred to as the reception-to-transmission (Rx-Tx) time difference. The initiator calculates the difference between the transmission time of the RTT measurement signal and the ToA of the RTT response signal, referred to as the transmission-to-reception (Tx-Rx) time difference. The propagation time (also referred to as the “time of flight”) between the initiator and the responder can be calculated from the Tx-Rx and Rx-Tx time differences. Based on the propagation time and the known speed of light, the distance between the initiator and the responder can be determined. For multi-RTT positioning, a UE performs an RTT procedure with multiple base stations to enable its location to be determined (e.g., using multilateration) based on the known locations of the base

stations. RTT and multi-RTT methods can be combined with other positioning techniques, such as UL-AoA and DL-AoD, to improve location accuracy.

[0110] The E-CID positioning method is based on radio resource management (RRM) measurements. In E-CID, the UE reports the serving cell ID, the timing advance (TA), and the identifiers, estimated timing, and signal strength of detected neighbor base stations. The location of the UE is then estimated based on this information and the known locations of the base station(s).

[0111] To assist positioning operations, a location server (e.g., location server 230, LMF 270, SLP 272) may provide assistance data to the UE. For example, the assistance data may include identifiers of the base stations (or the cells/TRPs of the base stations) from which to measure reference signals, the reference signal configuration parameters (e.g., the number of consecutive positioning subframes, periodicity of positioning subframes, muting sequence, frequency hopping sequence, reference signal identifier, reference signal bandwidth, etc.), and/or other parameters applicable to the particular positioning method. Alternatively, the assistance data may originate directly from the base stations themselves (e.g., in periodically broadcasted overhead messages, etc.). in some cases, the UE may be able to detect neighbor network nodes itself without the use of assistance data.

[0112] In the case of an OTDOA or DL-TDOA positioning procedure, the assistance data may further include an expected RSTD value and an associated uncertainty, or search window, around the expected RSTD. In some cases, the value range of the expected RSTD may be +/- 500 microseconds (μ s). In some cases, when any of the resources used for the positioning measurement are in FR1, the value range for the uncertainty of the expected RSTD may be +/- 32 μ s. In other cases, when all of the resources used for the positioning measurement(s) are in FR2, the value range for the uncertainty of the expected RSTD may be +/- 8 μ s.

[0113] A location estimate may be referred to by other names, such as a position estimate, location, position, position fix, fix, or the like. A location estimate may be geodetic and comprise coordinates (e.g., latitude, longitude, and possibly altitude) or may be civic and comprise a street address, postal address, or some other verbal description of a location. A location estimate may further be defined relative to some other known location or defined in absolute terms (e.g., using

latitude, longitude, and possibly altitude). A location estimate may include an expected error or uncertainty (e.g., by including an area or volume within which the location is expected to be included with some specified or default level of confidence).

[0114] FIG. 5 is a diagram 500 illustrating a base station (BS) 502 (which may correspond to any of the base stations described herein) in communication with a UE 504 (which may correspond to any of the UEs described herein). Referring to FIG. 5, the base station 502 may transmit a beamformed signal to the UE 504 on one or more transmit beams 502a, 502b, 502c, 502d, 502e, 502f, 502g, 502h, each having a beam identifier that can be used by the UE 504 to identify the respective beam. Where the base station 502 is beamforming towards the UE 504 with a single array of antennas (e.g., a single TRP/cell), the base station 502 may perform a “beam sweep” by transmitting first beam 502a, then beam 502b, and so on until lastly transmitting beam 502h. Alternatively, the base station 502 may transmit beams 502a – 502h in some pattern, such as beam 502a, then beam 502h, then beam 502b, then beam 502g, and so on. Where the base station 502 is beamforming towards the UE 504 using multiple arrays of antennas (e.g., multiple TRPs/cells), each antenna array may perform a beam sweep of a subset of the beams 502a – 502h. Alternatively, each of beams 502a – 502h may correspond to a single antenna or antenna array.

[0115] FIG. 5 further illustrates the paths 512c, 512d, 512e, 512f, and 512g followed by the beamformed signal transmitted on beams 502c, 502d, 502e, 502f, and 502g, respectively. Each path 512c, 512d, 512e, 512f, 512g may correspond to a single “multipath” or, due to the propagation characteristics of radio frequency (RF) signals through the environment, may be comprised of a plurality (a cluster) of “multipaths.” Note that although only the paths for beams 502c – 502g are shown, this is for simplicity, and the signal transmitted on each of beams 502a – 502h will follow some path. In the example shown, the paths 512c, 512d, 512e, and 512f are straight lines, while path 512g reflects off an obstacle 520 (e.g., a building, vehicle, terrain feature, etc.).

[0116] The UE 504 may receive the beamformed signal from the base station 502 on one or more receive beams 504a, 504b, 504c, 504d. Note that for simplicity, the beams illustrated in FIG. 5 represent either transmit beams or receive beams,

depending on which of the base station 502 and the UE 504 is transmitting and which is receiving. Thus, the UE 504 may also transmit a beamformed signal to the base station 502 on one or more of the beams 504a – 504d, and the base station 502 may receive the beamformed signal from the UE 504 on one or more of the beams 502a – 502h.

[0117] In an aspect, the base station 502 and the UE 504 may perform beam training to align the transmit and receive beams of the base station 502 and the UE 504. For example, depending on environmental conditions and other factors, the base station 502 and the UE 504 may determine that the best transmit and receive beams are 502d and 504b, respectively, or beams 502e and 504c, respectively. The direction of the best transmit beam for the base station 502 may or may not be the same as the direction of the best receive beam, and likewise, the direction of the best receive beam for the UE 504 may or may not be the same as the direction of the best transmit beam. Note, however, that aligning the transmit and receive beams is not necessary to perform a downlink angle-of-departure (DL-AoD) or uplink angle-of-arrival (UL-AoA) positioning procedure.

[0118] To perform a DL-AoD positioning procedure, the base station 502 may transmit reference signals (e.g., PRS, CRS, TRS, CSI-RS, PSS, SSS, etc.) to the UE 504 on one or more of beams 502a – 502h, with each beam having a different transmit angle. The different transmit angles of the beams will result in different received signal strengths (e.g., RSRP, RSRQ, SINR, etc.) at the UE 504. Specifically, the received signal strength will be lower for transmit beams 502a – 502h that are further from the line of sight (LOS) path 510 between the base station 502 and the UE 504 than for transmit beams 502a – 502h that are closer to the LOS path 510.

[0119] In the example of FIG. 5, if the base station 502 transmits reference signals to the UE 504 on beams 502c, 502d, 502e, 502f, and 502g, then transmit beam 502e is best aligned with the LOS path 510, while transmit beams 502c, 502d, 502f, and 502g are not. As such, beam 502e is likely to have a higher received signal strength at the UE 504 than beams 502c, 502d, 502f, and 502g. Note that the reference signals transmitted on some beams (e.g., beams 502c and/or 502f) may not reach the UE 504, or energy reaching the UE 504 from these beams may be so low that the energy may not be detectable or at least can be ignored.

[0120] The UE 504 can report the received signal strength, and optionally, the associated measurement quality, of each measured transmit beam 502c – 502g to the base station 502, or alternatively, the identity of the transmit beam having the highest received signal strength (beam 502e in the example of FIG. 5). Alternatively or additionally, if the UE 504 is also engaged in a round-trip-time (RTT) or time-difference of arrival (TDOA) positioning session with at least one base station 502 or a plurality of base stations 502, respectively, the UE 504 can report reception-to-transmission (Rx-Tx) time difference or reference signal time difference (RSTD) measurements (and optionally the associated measurement qualities), respectively, to the serving base station 502 or other positioning entity. In any case, the positioning entity (e.g., the base station 502, a location server, a third-party client, UE 504, etc.) can estimate the angle from the base station 502 to the UE 504 as the AoD of the transmit beam having the highest received signal strength at the UE 504, here, transmit beam 502e.

[0121] In one aspect of DL-AoD-based positioning, where there is only one involved base station 502, the base station 502 and the UE 504 can perform a round-trip-time (RTT) procedure to determine the distance between the base station 502 and the UE 504. Thus, the positioning entity can determine both the direction to the UE 504 (using DL-AoD positioning) and the distance to the UE 504 (using RTT positioning) to estimate the location of the UE 504. Note that the AoD of the transmit beam having the highest received signal strength does not necessarily lie along the LOS path 510, as shown in FIG. 5. However, for DL-AoD-based positioning purposes, it is assumed to do so.

[0122] In another aspect of DL-AoD-based positioning, where there are multiple involved base stations 502, each involved base station 502 can report, to the serving base station 502, the determined AoD from the respective base station 502 to the UE 504, or the RSRP measurements. The serving base station 502 may then report the AoDs or RSRP measurements from the other involved base station(s) 502 to the positioning entity (e.g., UE 504 for UE-based positioning or a location server for UE-assisted positioning). With this information, and knowledge of the base stations' 502 geographic locations, the positioning entity can estimate a location of the UE 504 as the intersection of the determined AoDs. There should be at least two involved base stations 502 for a two-dimensional

(2D) location solution, but as will be appreciated, the more base stations 502 that are involved in the positioning procedure, the more accurate the estimated location of the UE 504 will be.

[0123] To perform an UL-AoA positioning procedure, the UE 504 transmits uplink reference signals (e.g., UL-PRS, SRS, DMRS, etc.) to the base station 502 on one or more of uplink transmit beams 504a – 504d. The base station 502 receives the uplink reference signals on one or more of uplink receive beams 502a – 502h. The base station 502 determines the angle of the best receive beams 502a – 502h used to receive the one or more reference signals from the UE 504 as the AoA from the UE 504 to itself. Specifically, each of the receive beams 502a – 502h will result in a different received signal strength (e.g., RSRP, RSRQ, SINR, etc.) of the one or more reference signals at the base station 502. Further, the channel impulse response of the one or more reference signals will be smaller for receive beams 502a – 502h that are further from the actual LOS path between the base station 502 and the UE 504 than for receive beams 502a – 502h that are closer to the LOS path. Likewise, the received signal strength will be lower for receive beams 502a – 502h that are further from the LOS path than for receive beams 502a – 502h that are closer to the LOS path. As such, the base station 502 identifies the receive beam 502a – 502h that results in the highest received signal strength and, optionally, the strongest channel impulse response, and estimates the angle from itself to the UE 504 as the AoA of that receive beam 502a – 502h. Note that as with DL-AoD-based positioning, the AoA of the receive beam 502a – 502h resulting in the highest received signal strength (and strongest channel impulse response if measured) does not necessarily lie along the LOS path 510. However, for UL-AoA-based positioning purposes in FR2, it may be assumed to do so.

[0124] Note that while the UE 504 is illustrated as being capable of beamforming, this is not necessary for DL-AoD and UL-AoA positioning procedures. Rather, the UE 504 may receive and transmit on an omni-directional antenna.

[0125] Where the UE 504 is estimating its location (i.e., the UE is the positioning entity), it needs to obtain the geographic location of the base station 502. The UE 504 may obtain the location from, for example, the base station 502 itself or a location server (e.g., location server 230, LMF 270, SLP 272). With the

knowledge of the distance to the base station 502 (based on the RTT or timing advance), the angle between the base station 502 and the UE 504 (based on the UL-AoA of the best receive beam 502a – 502h), and the known geographic location of the base station 502, the UE 504 can estimate its location.

[0126] Alternatively, where a positioning entity, such as the base station 502 or a location server, is estimating the location of the UE 504, the base station 502 reports the AoA of the receive beam 502a – 502h resulting in the highest received signal strength (and optionally strongest channel impulse response) of the reference signals received from the UE 504, or all received signal strengths and channel impulse responses for all receive beams 502 (which allows the positioning entity to determine the best receive beam 502a – 502h). The base station 502 may additionally report the Rx-Tx time difference to the UE 504. The positioning entity can then estimate the location of the UE 504 based on the UE's 504 distance to the base station 502, the AoA of the identified receive beam 502a – 502h, and the known geographic location of the base station 502.

[0127] FIG. 6 illustrates an example system 600 for wireless communication using a reconfigurable intelligent surface (RIS) 610, according to aspects of the disclosure. An RIS (e.g., RIS 610) is a two-dimensional surface comprising a large number of low-cost, low-power near-passive reflecting elements whose properties are reconfigurable (by software) rather than static. For example, by carefully tuning the phase shifts of the reflecting elements (using software), the scattering, absorption, reflection, and diffraction properties of an RIS can be changed over time. In that way, the electromagnetic (EM) properties of an RIS can be engineered to collect wireless signals from a transmitter (e.g., a base station, a UE, etc.) and passively beamform them towards a target receiver (e.g., another base station, another UE, etc.). In the example of FIG. 6, a first base station 602-1 controls the reflective properties of an RIS 610 in order to communicate with a first UE 604-1.

[0128] The goal of RIS technology is to create smart radio environments, where the wireless propagation conditions are co-engineered with the physical layer signaling. This enhanced functionality of the system 600 can provide technical benefits in a number of scenarios.

[0129] As a first example scenario, as shown in FIG. 6, the first base station 602-1 (e.g., any of the base station described herein) is attempting to transmit downlink wireless signals to the first UE 604-1 and a second UE 604-2 (e.g., any two of the UEs described herein, collectively, UEs 604) on a plurality of downlink transmit beams, labeled “0,” “1,” “2,” and “3.” However, unlike the second UE 604-2, because the first UE 604-1 is behind an obstacle 620 (e.g., a building, a hill, or another type of obstacle), it cannot receive the wireless signal on what would otherwise be the line-of-sight (LOS) beam from the first base station 602-1, that is, the downlink transmit beam labeled “2.” In this scenario, the first base station 602-1 may instead use the downlink transmit beam labeled “1” to transmit the wireless signal to the RIS 610, and configure the RIS 610 to reflect/beamform the incoming wireless signal towards the first UE 604-1. The first base station 602-1 can thereby transmit the wireless signal around the obstacle 620.

[0130] Note that the first base station 602-1 may also configure the RIS 610 for the first UE’s 604-1 use in the uplink. In that case, the first base station 602-1 may configure the RIS 610 to reflect an uplink signal from the first UE 604-1 to the first base station 602-1, thereby enabling the first UE 604-1 to transmit the uplink signal around the obstacle 620.

[0131] As another example scenario in which system 600 can provide a technical advantage, the first base station 602-1 may be aware that the obstacle 620 may create a “dead zone,” that is, a geographic area in which the downlink wireless signals from the first base station 602-1 are too attenuated to be reliably detected by a UE within that area (e.g., the first UE 604-1). In this scenario, the first base station 602-1 may configure the RIS 610 to reflect downlink wireless signals into the dead zone in order to provide coverage to UEs that may be located there, including UEs about which the first base station 602-1 is not aware.

[0132] FIG. 6 also illustrates a second base station 602-2 that may transmit downlink wireless signals to one or both of the UEs 604. As an example, the first base station 602-1 may be a serving base station for the UEs 604 and the second base station 602-2 may be a neighboring base station. The second base station 602-2 may transmit downlink positioning reference signals to one or both of the UEs 604 as part of a positioning procedure involving the UE(s) 604. Alternatively or additionally, the second base station 602-2 may be a secondary cell for one or

both of the UEs 604. In some cases, the second base station 602-2 may also be able to reconfigure the RIS 610, provided it is not being controlled by the first base station 602-1 at the time.

[0133] Referring to FIG. 6, the RIS 610 may be either a mode 1 RIS which is essentially a reconfigurable mirror, or a mode 2 RIS that is more enhanced and which supports relay mode operation (amplify and forward). For mode 1 RIS, it is assumed that the hardware group delay at RIS is negligible. For mode 2 RIS, in some designs, it may be assumed that the hardware group delay of the respective RIS is non-negligible. In this case, a respective gNB may further indicate whether the respective mode 2 RIS supports baseband processing, and may compute and/or report an associated Rx-Tx time difference. In some designs, the gNB may also report if RIS could compute/report its Rx-Tx time difference.

[0134] FIG. 7 is a diagram of an example architecture of a RIS 700, according to aspects of the disclosure. As shown in FIG. 7, a RIS 700 (which may correspond to RIS 610 in FIG. 6) mainly consists of a planar surface 710 and a controller 720. The planar surface 710 may be constructed of one or more layers of material. In the example of FIG. 7, the planar surface 710 may consist of three layers. In this case, the outer layer has a large number of reflecting elements 712 printed on a dielectric substrate to directly act on the incident signals. The middle layer is a copper panel to avoid signal/energy leakage. The last layer is a circuit board that is used for tuning the reflection coefficients of the reflecting elements 712 and is operated by the controller 720. The controller 720 may be a low-power processor, such as a field-programmable gate array (FPGA).

[0135] In a typical operating scenario, the optimal reflection coefficients of the RIS 700 is calculated at the base station (e.g., the first base station 602-1 in FIG. 6), and then sent to the controller 720 through a dedicated feedback link. The design of the reflection coefficients depends on the channel state information (CSI), which is only updated when the CSI changes, which is on a much longer time scale than the data symbol duration. As such, low-rate information exchange is sufficient for the dedicated control link, which can be implemented using low-cost copper lines or simple cost-efficient wireless transceivers.

[0136] Each reflecting element 712 is coupled to a positive-intrinsic negative (PIN) diode 714. In addition, a biasing line 716 connects each reflecting element

712 in a column to the controller 720. By controlling the voltage through the biasing line 716, the PIN diodes 714 can switch between ‘on’ and ‘off’ modes. This can realize a phase shift difference of π (pi) in radians. To increase the number of phase shift levels, more PIN diodes 714 can be coupled to each reflecting element 712.

[0137] An RIS, such as RIS 700, has important advantages for practical implementations. For example, the reflecting elements 712 only passively reflect the incoming signals without any sophisticated signal processing operations that would require RF transceiver hardware. As such, compared to conventional active transmitters, the RIS 700 can operate with several orders of magnitude lower cost in terms of hardware and power consumption. Additionally, due to the passive nature of the reflecting elements 712, an RIS 700 can be fabricated with light weight and limited layer thickness, and as such, can be readily installed on a wall, a ceiling, signage, a street lamp, etc. Further, the RIS 700 naturally operates in full-duplex (FD) mode without self-interference or introducing thermal noise. Therefore, it can achieve higher spectral efficiency than active half-duplex (HD) relays, despite their lower signal processing complexity than that of active FD relays requiring sophisticated self-interference cancellation.

[0138] As noted above, various device types may be characterized as UEs. Starting in 3GPP Rel. 17, a number of these UE types (so-called low-tier UEs) are being allocated a new UE classification denoted as Reduced Capability (‘RedCap’) or ‘NR-Light’. Examples of UE types that fall under the RedCap classification include wearable devices (e.g., smart watches, etc.), industrial sensors, video cameras (e.g., surveillance cameras, etc.), and so on. Generally, the UE types grouped under the RedCap classification are associated with lower communicative capacity. For example, relative to ‘normal’ UEs (e.g., UEs not classified as RedCap), RedCap UEs may be limited in terms of maximum bandwidth (e.g., 5 MHz, 10 MHz, 20 MHz, etc.), maximum transmission power (e.g., 20 dBm, 14 dBm, etc.), number of receive antennas (e.g., 1 receive antenna, 2 receive antennas, etc.), and so on. Some RedCap UEs may also be sensitive in terms of power consumption (e.g., requiring a long battery life, such as several years) and may be highly mobile. Moreover, in some designs, it is generally

desirable for RedCap UEs to co-exist with UEs implementing protocols such as eMBB, URLLC, LTE NB-IoT/MTC, and so on.

[0139] Due to its limited capability, a RedCap UE may have difficulty in hearing or detecting PRS, particularly from non-serving gNBs which may be further away from the RedCap UE than a serving gNB (e.g., due to limited reception bandwidth, Rx antennas, baseband processing capability, etc.). Likewise, the RedCap UE may be associated with poor SRS measurements (e.g., limited capability to measure UL-SRS-P at one or more neighbor gNBs, limited capability to measure UL-SRS-P reflections off RIS by the UE itself, etc.). In some designs, low-power UE positioning schemes may be implemented for RedCap UEs. However, such implementations generally require the RedCap UEs to be in coverage (e.g., UL and DL coverage) of a serving gNB as well as non-serving gNBs. In some designs, RISs can be treated as positioning anchors for RIS-aided positioning of UEs (e.g., particularly for indoor scenarios).

[0140] Aspects of the disclosure are thereby directed to location assistance data for RIS-aided positioning. Such aspects may provide various technical advantages, such as improved positioning accuracy, particularly for indoor positioning, positioning of RedCap UEs, and so on.

[0141] FIG. 8 illustrates an exemplary process 800 of communications according to an aspect of the disclosure. The process 800 of FIG. 8 is performed by a UE, which may correspond to UE 302 as an example.

[0142] Referring to FIG. 8, at 810, UE 302 (e.g., receiver 312 or 322, etc.) receives, from a network component (e.g., a base station), location assistance data including information associated with one or more RISs. In some designs, the network component may correspond to a serving gNB of UE 302. In other designs, the network component may correspond to an LMF or location server. In an example, the location assistance data may be broadcast location assistance data (e.g., sent out in a particular location region to any listening UE) or unicast location assistance data (e.g., sent out to a particular UE based on UE-specific information). Various types of information that may be sent in association with the RIS(s), as will be described below in more detail. In an example, a means for performing the receiving of 810 may include receiver 312 or 322 of UE 302.

[0143] Referring to FIG. 8, at 820, UE 302 (e.g., receiver 312 or 322, transmitter 314 or 324, processing system 332, RIS module 342, etc.) performs one or more location procedures based on the location assistance data. As will be described in more detail, various types of location procedure(s) may be performed at 820, such as transmitting UL or SL SRS-P via reflection off of RIS(s), measuring DL-PRS or SL-PRS (e.g., ToA, RSRP, DL-AoD, etc.) that is reflected off of RIS(s), and so on. In an example, a means for performing the location procedure(s) of 820 may include receiver 312 or 322, transmitter 314 or 324, processing system 332, RIS module 342, etc.

[0144] FIG. 9 illustrates an exemplary process 900 of communications according to an aspect of the disclosure. The process 900 of FIG. 9 is performed by a network component, which may correspond to BS 304, an LMF or a location server (e.g., integrated with BS 304 or at a network entity 306 such as a core network component or remote server, etc.).

[0145] Referring to FIG. 9, at 910, the network component (e.g., processing system 384 or 394, RIS module 388 or 398, etc.) determines location assistance data comprising information associated with one or more RISs. Various types of information that may be sent in association with the RIS(s), as will be described below in more detail. In an example, a means for performing the determination of 910 may include processing system 384 or 394, RIS module 388 or 398, etc., of BS 304 or network entity 306.

[0146] Referring to FIG. 9, at 920, the network component (e.g., transmitter 354 or 364, network interface(s) 390, etc.) transmits, to a UE, the location assistance data to facilitate one or more location procedures based on the location assistance data. In an example, the location assistance data may be broadcast location assistance data (e.g., sent out in a particular location region to any listening UE) or unicast location assistance data (e.g., sent out to a particular UE based on UE-specific information). As will be described in more detail, various types of location procedure(s) may be performed based on the location assistance data, such as transmitting UL or SL SRS-P via reflection off of RIS(s), measuring DL-PRS or SL-PRS (e.g., ToA, RSRP, DL-AoD, etc.) that is reflected off of RIS(s), and so on. In an example, a means for performing the transmission of 920 may

include transmitter 354 or 364, network interface(s) 390, etc., of BS 304 or network entity 306.

[0147] Referring to FIGS. 8-9, in some designs, the information may include a notification of the presence of the one or more RISs in an area. In some designs, the area corresponds to a cell (e.g., if the network does not have any history of the location of UE 302, the network may provide a cell-level RIS notification), or the area is based on a position estimate of the UE (e.g., if the network has a recent positioning fix for UE 302, such as within a threshold of times or x seconds, the network may provide the UE with a notification of RIS locations within a threshold distance of UE 302, such as y meter, i.e., a UE location level notification), or a combination thereof. In some designs, if the notification is provided with respect to multiple RISs in the location regions, then the information in the location assistance data may include a respective RIS identifier for each of the multiple RISs.

[0148] Referring to FIGS. 8-9, in some designs, the one or more location procedures are associated with UE-based position estimation of the UE, and the information may include a respective location associated with each of the one or more RISs. By contrast, for UE-assisted positioning, UE 302 need not know the actual RIS locations. In other words, in some designs, the RIS locations may be known to the position estimation entity rather than all devices associated with transmitting and/or measuring reference signals for positioning (RS-Ps) such as DL-PRS, SL-PRS, UL-SRS-P, SL-SRS-P, and so on.

[0149] Referring to FIGS. 8-9, in some designs, for each of the one or more RISs, the information may include an indication of whether the respective RIS is a passive RIS (e.g., mode 1 RIS) or a relay RIS (e.g., mode 2 RIS capable of amplifying and forwarding RS-Ps). In some designs, at least one of the one or more RISs is indicated as a relay RIS, and the information further includes, with respect to the at least one RIS, an indication of a gain of RIS reflection, a group delay, or a combination thereof (e.g., for UE-based positioning). For UE-assisted positioning, such information can be omitted from the location assistance data and can instead be known at the position estimation entity, i.e., LMF. In some designs, the group delay may be calibrated when the RIS is setup, and thereafter assumed to be fixed. In other designs, the group delay for the RIS may be measured

periodically or in a more dynamic manner, and updated from time to time (e.g., for each positioning session, etc.).

[0150] Referring to FIGS. 8-9, in some designs, the one or more location procedures are associated with at least one RS-P communicated between the UE and a wireless node (e.g., a serving or non-serving gNB, a UE such as a reference UE or anchor UE with a known location from a recent positioning fix, etc.) via reflection off of the one or more RISs. For example, the at least one RS-P comprises at least one uplink (UL) or sidelink (SL) SRS-P transmitted by the UE, or the at least one RS-P comprises at least one DL-PRS or SL-PRS transmitted by the wireless node, or a combination thereof. In an example, one or multiple PRS could be associated with one or multiple specific RIS (e.g., the network could signal the associated RIS ID when configuring the PRS). Likewise, in another example, one or multiple SRS could be associated with one or multiple specific RIS (e.g., the network could signal the associated RIS ID when configuring the SRS). In some designs, the information may include an association between the at least one RS-P and the one or more RISs.

[0151] Referring to FIGS. 8-9, in some designs, the at least one RS-P may include (or may correspond to) at least one DL or SL PRS transmitted by the wireless node. In this case, the information may include first quasi-colocation (QCL) information associated with the downlink or sidelink PRS transmitted by the wireless node, and the information may include second QCL information associated with the at least one RS-P as reflected off of the one or more RISs. In some designs, a QCL source associated with the first QCL information, the second QCL information, or both, may correspond to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS). For example, in some scenarios, UE may be expected to conduct positioning measurement with the same positioning RS, which is both transmitted by the gNB and reflected by RIS. To enhance measurement quality, two sets of QCL could be configured (e.g., the first set of QCL is respect the gNB's transmission, and the second set of QCL is respect to the RIS's reflection). In this case, the QCL source could be other positioning RS or SSB/CSIRS. The RIS could reflect the SSB /CSIRS transmitted by gNB, hence UE could find the reference Rx beam for reception of signal reflected by RIS through measuring the reflected SSB/CSIRS.

[0152] Referring to FIGS. 8-9, in some the legacy NR positioning systems, *nr-DL-PRS-ExpectedRSTD*, *nr-DL-PRS-ExpectedRSTD-Uncertainty* are provided for each pair of DL PRS Resource Sets (target and reference gNB) in location assistance data. For example, the UE may expect to be configured with higher layer parameter *nr-DL-PRS-ExpectedRSTD*, which defines the time difference with respect to the received DL subframe timing the UE is expected to receive DL PRS, and *nr-DL-PRS-ExpectedRSTD-Uncertainty*, which defines a search window around the expected RSTD. In some designs, the at least one RS-P communicated between UE 302 and the wireless node via the RIS(s) may include one or more PRS search window parameters. In some designs, the one or more PRS search window parameters may include an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE. In a more specific example, the new timing uncertainty parameters may be named as “*nr-RIS-DL-PRS-ExpectedRSTD*” and “*nr-RIS-DL-PRS-ExpectedRSTD-Uncertainty*”, which are derived based on the location of RIS. The “*nr-RIS-DL-PRS-ExpectedRSTD*” may define the time difference with respect to the received DL subframe timing the UE is expected to receive DL-PRS, which is reflected by a specific RIS. The “*nr-RIS-DL-PRS-ExpectedRSTD-Uncertainty*” may define a search window around the “*nr-RIS-DL-PRS-ExpectedRSTD*”. UE could be guided to optimize the reception of RIS reflected PRS based on “*nr-RIS-DL-PRS-ExpectedRSTD*” and “*nr-RIS-DL-PRS-ExpectedRSTD-Uncertainty*”.

[0153] Referring to FIGS. 8-9, in some designs, the one or more one or more location procedures may include a downlink angle of departure (DL-AoD) positioning session of the UE. In a further example, the information may include beam information of each positioning reference signal (PRS) for the one or more RISs. Some of the beam information may be associated with boresight, as depicted in the arrangement 1000 of FIG. 10. More specifically, in some designs, the beam information may include:

- a PRS identifier and associated RIS identifier, or
- RIS orientation (e.g., to compute boresight direction, e.g., the bearing angle α , the downtilt angle β and the slant angle γ , which could be used to transform the RIS

orientation from location coordinate system (LCS) to group coordinate system (GCS), or

- an Azimuth and elevation of the respective PRS beam), or
- a beam width of the respective PRS beam (e.g., the beam-width could be 3-dB/6-dB/12-dB beam-width, e.g., the beam-width may be labeled with its beam spatial dimension, for example, Azimuth and elevation), or
- a boresight direction or beamwidth uncertainty (e.g., the boresight/beam-width uncertainty could be 0.5-dB/1-dB/3-dB based measurement, e.g., the beam-width uncertainty should be labeled with its beam spatial dimension), or
- a power level of one or more side lobes or a back lobe with respect to boresight (e.g., -20 dB), or
- a combination thereof.

[0154] In the detailed description above it can be seen that different features are grouped together in examples. This manner of disclosure should not be understood as an intention that the example clauses have more features than are explicitly mentioned in each clause. Rather, the various aspects of the disclosure may include fewer than all features of an individual example clause disclosed. Therefore, the following clauses should hereby be deemed to be incorporated in the description, wherein each clause by itself can stand as a separate example. Although each dependent clause can refer in the clauses to a specific combination with one of the other clauses, the aspect(s) of that dependent clause are not limited to the specific combination. It will be appreciated that other example clauses can also include a combination of the dependent clause aspect(s) with the subject matter of any other dependent clause or independent clause or a combination of any feature with other dependent and independent clauses. The various aspects disclosed herein expressly include these combinations, unless it is explicitly expressed or can be readily inferred that a specific combination is not intended (e.g., contradictory aspects, such as defining an element as both an insulator and a conductor). Furthermore, it is also intended that aspects of a clause can be included in any other independent clause, even if the clause is not directly dependent on the independent clause.

[0155] Implementation examples are described in the following numbered clauses:

[0156] Clause 1. A method of operating a user equipment (UE), comprising: receiving, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and performing one or more location procedures based on the location assistance data.

[0157] Clause 2. The method of clause 1, wherein the information comprises a notification of the presence of the one or more RISs in an area.

[0158] Clause 3. The method of clause 2, wherein the area corresponds to a cell, or wherein the area is based on a position estimate of the UE, or a combination thereof.

[0159] Clause 4. The method of any of clauses 2 to 3, wherein the one or more RISs include multiple RISs, and wherein the information comprises a respective RIS identifier for each of the multiple RISs.

[0160] Clause 5. The method of any of clauses 1 to 4, wherein the one or more location procedures are associated with UE-based position estimation of the UE, and wherein the information comprises a respective location associated with each of the one or more RISs.

[0161] Clause 6. The method of any of clauses 1 to 5, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

[0162] Clause 7. The method of clause 6, wherein at least one of the one or more RISs is indicated as a relay RIS, and wherein the information further includes, with respect to the at least one RIS, an indication of a gain of RIS reflection, a group delay, or a combination thereof.

[0163] Clause 8. The method of any of clauses 1 to 7, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

[0164] Clause 9. The method of clause 8, wherein the at least one RS-P comprises at least one uplink or sidelink sounding reference signal for positioning (SRS-P) transmitted by the UE, or wherein the at least one RS-P comprises at least one

downlink or sidelink positioning reference signal (PRS) transmitted by the wireless node, or a combination thereof.

[0165] Clause 10. The method of clause 9, wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node, wherein the information comprises first quasi-colocation (QCL) information associated with the at least one downlink or sidelink PRS transmitted by the wireless node, and wherein the information comprises second QCL information associated the at least one RS-P as reflected off of the one or more RISs.

[0166] Clause 11. The method of clause 10, wherein a QCL source associated with the first QCL information, the second QCL information, or both, corresponds to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS).

[0167] Clause 12. The method of any of clauses 9 to 11, wherein the at least one RS-P comprises the at least one PRS transmitted by the wireless node, wherein the information comprises one or more PRS search window parameters.

[0168] Clause 13. The method of clause 12, wherein the one or more PRS search window parameters comprise an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE.

[0169] Clause 14. The method of any of clauses 8 to 13, wherein the information comprises an association between the at least one RS-P and the one or more RISs.

[0170] Clause 15. The method of any of clauses 1 to 14, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

[0171] Clause 16. The method of clause 15, wherein the information comprises beam information of each positioning reference signal (PRS) for the one or more RISs.

[0172] Clause 17. The method of clause 16, wherein the beam information includes: a PRS identifier and associated RIS identifier, or RIS orientation, or an Azimuth and elevation of the respective PRS beam, or a beam width of the respective PRS beam, or a boresight direction or beamwidth uncertainty, or a

power level of one or more side lobes or a back lobe with respect to boresight, or a combination thereof.

[0173] Clause 18. A method of operating a network component, comprising: determining location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and transmitting, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

[0174] Clause 19. The method of clause 18, wherein the information comprises a notification of the presence of the one or more RISs in an area.

[0175] Clause 20. The method of clause 19, wherein the area corresponds to a cell, or wherein the area is based on a position estimate of the UE, or a combination thereof.

[0176] Clause 21. The method of any of clauses 19 to 20, wherein the one or more RISs include multiple RISs, and wherein the information comprises a respective RIS identifier for each of the multiple RISs.

[0177] Clause 22. The method of any of clauses 18 to 21, wherein the one or more location procedures are associated with UE-based position estimation of the UE, and wherein the information comprises a respective location associated with each of the one or more RISs.

[0178] Clause 23. The method of any of clauses 18 to 22, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

[0179] Clause 24. The method of clause 23, wherein at least one of the one or more RISs is indicated as a relay RIS, and wherein the information further includes, with respect to the at least one RIS, an indication of a gain of RIS reflection, a group delay, or a combination thereof.

[0180] Clause 25. The method of any of clauses 18 to 24, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

[0181] Clause 26. The method of clause 25, wherein the at least one RS-P comprises at least one uplink or sidelink sounding reference signal for positioning (SRS-P) transmitted by the UE, or wherein the at least one RS-P comprises at least

one downlink or sidelink positioning reference signal (PRS) transmitted by the wireless node, or a combination thereof.

[0182] Clause 27. The method of clause 26, wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node, wherein the information comprises first quasi-colocation (QCL) information associated with the at least one downlink or sidelink PRS transmitted by the wireless node, and wherein the information comprises second QCL information associated with the at least one RS-P as reflected off of the one or more RISs.

[0183] Clause 28. The method of clause 27, wherein a QCL source associated with the first QCL information, the second QCL information, or both, corresponds to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS).

[0184] Clause 29. The method of any of clauses 26 to 28, wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node, wherein the information comprises one or more PRS search window parameters.

[0185] Clause 30. The method of clause 29, wherein the one or more PRS search window parameters comprise an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE.

[0186] Clause 31. The method of any of clauses 25 to 30, wherein the information comprises an association between the at least one RS-P and the one or more RISs.

[0187] Clause 32. The method of any of clauses 18 to 31, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

[0188] Clause 33. The method of clause 32, wherein the information comprises beam information of each positioning reference signal (PRS) for the one or more RISs.

[0189] Clause 34. The method of clause 33, wherein the beam information includes: a PRS identifier and associated RIS identifier, or RIS orientation, or an Azimuth and elevation of the respective PRS beam, or a beam width of the respective PRS beam, or a boresight direction or beamwidth uncertainty, or a

power level of one or more side lobes or a back lobe with respect to boresight, or a combination thereof.

[0190] Clause 35. An apparatus comprising a memory and at least one processor communicatively coupled to the memory, the memory and the at least one processor configured to perform a method according to any of clauses 1 to 34.

[0191] Clause 36. An apparatus comprising means for performing a method according to any of clauses 1 to 34.

[0192] Clause 37. A non-transitory computer-readable medium storing computer-executable instructions, the computer-executable comprising at least one instruction for causing a computer or processor to perform a method according to any of clauses 1 to 34.

[0193] Those of skill in the art will appreciate that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0194] Further, those of skill in the art will appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the aspects disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

[0195] The various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an ASIC, a field-programmable gate array (FPGA), or other programmable logic device,

discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0196] The methods, sequences and/or algorithms described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in random access memory (RAM), flash memory, read-only memory (ROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An example storage medium is coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal (e.g., UE). In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

[0197] In one or more example aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any

connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[0198] While the foregoing disclosure shows illustrative aspects of the disclosure, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. The functions, steps and/or actions of the method claims in accordance with the aspects of the disclosure described herein need not be performed in any particular order. Furthermore, although elements of the disclosure may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated.

CLAIMS

What is claimed is:

1. A method of operating a user equipment (UE), comprising:
receiving, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
performing one or more location procedures based on the location assistance data.
2. The method of claim 1, wherein the information comprises a notification of the presence of the one or more RISs in an area.
3. The method of claim 2,
wherein the area corresponds to a cell, or
wherein the area is based on a position estimate of the UE, or
a combination thereof.
4. The method of claim 2,
wherein the one or more RISs include multiple RISs, and
wherein the information comprises a respective RIS identifier for each of the multiple RISs.
5. The method of claim 1,
wherein the one or more location procedures are associated with UE-based position estimation of the UE, and
wherein the information comprises a respective location associated with each of the one or more RISs.
6. The method of claim 1, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.
7. The method of claim 6,
wherein at least one of the one or more RISs is indicated as a relay RIS, and

wherein the information further includes, with respect to the at least one RIS, an indication of a gain of RIS reflection, a group delay, or a combination thereof.

8. The method of claim 1, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

9. The method of claim 8,
wherein the at least one RS-P comprises at least one uplink or sidelink sounding reference signal for positioning (SRS-P) transmitted by the UE, or
wherein the at least one RS-P comprises at least one downlink or sidelink positioning reference signal (PRS) transmitted by the wireless node, or
a combination thereof.

10. The method of claim 9,
wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node,
wherein the information comprises first quasi-colocation (QCL) information associated with the at least one downlink or sidelink PRS transmitted by the wireless node, and
wherein the information comprises second QCL information associated the at least one RS-P as reflected off of the one or more RISs.

11. The method of claim 10, wherein a QCL source associated with the first QCL information, the second QCL information, or both, corresponds to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS).

12. The method of claim 9,
wherein the at least one RS-P comprises the at least one PRS transmitted by the wireless node,
wherein the information comprises one or more PRS search window parameters.

13. The method of claim 12, wherein the one or more PRS search window parameters comprise an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE.

14. The method of claim 8, wherein the information comprises an association between the at least one RS-P and the one or more RISs.

15. The method of claim 1, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

16. The method of claim 15, wherein the information comprises beam information of each positioning reference signal (PRS) for the one or more RISs.

17. The method of claim 16, wherein the beam information includes:
a PRS identifier and associated RIS identifier, or
RIS orientation, or
an Azimuth and elevation of the respective PRS beam, or
a beam width of the respective PRS beam, or
a boresight direction or beamwidth uncertainty, or
a power level of one or more side lobes or a back lobe with respect to boresight,
or
a combination thereof.

18. A method of operating a network component, comprising:
determining location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
transmitting, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

19. The method of claim 18, wherein the information comprises a notification of the presence of the one or more RISs in an area.

20. The method of claim 19,
wherein the area corresponds to a cell, or
wherein the area is based on a position estimate of the UE, or
a combination thereof.
21. The method of claim 19,
wherein the one or more RISs include multiple RISs, and
wherein the information comprises a respective RIS identifier for each of the
multiple RISs.
22. The method of claim 18,
wherein the one or more location procedures are associated with UE-based
position estimation of the UE, and
wherein the information comprises a respective location associated with each of
the one or more RISs.
23. The method of claim 18, wherein, for each of the one or more RISs, the
information comprises an indication of whether the respective RIS is a passive RIS or a
relay RIS.
24. The method of claim 23,
wherein at least one of the one or more RISs is indicated as a relay RIS, and
wherein the information further includes, with respect to the at least one RIS, an
indication of a gain of RIS reflection, a group delay, or a combination thereof.
25. The method of claim 18, wherein the one or more location procedures are
associated with at least one reference signal for positioning (RS-P) communicated
between the UE and a wireless node via reflection off of the one or more RISs.
26. The method of claim 25,
wherein the at least one RS-P comprises at least one uplink or sidelink sounding
reference signal for positioning (SRS-P) transmitted by the UE, or

wherein the at least one RS-P comprises at least one downlink or sidelink positioning reference signal (PRS) transmitted by the wireless node, or a combination thereof.

27. The method of claim 26,

wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node,

wherein the information comprises first quasi-colocation (QCL) information associated with the at least one downlink or sidelink PRS transmitted by the wireless node, and

wherein the information comprises second QCL information associated the at least one RS-P as reflected off of the one or more RISs.

28. The method of claim 27, wherein a QCL source associated with the first QCL information, the second QCL information, or both, corresponds to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS).

29. The method of claim 26,

wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node,

wherein the information comprises one or more PRS search window parameters.

30. The method of claim 29, wherein the one or more PRS search window parameters comprise an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE.

31. The method of claim 25, wherein the information comprises an association between the at least one RS-P and the one or more RISs.

32. The method of claim 18, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

33. The method of claim 32, wherein the information comprises beam information of each positioning reference signal (PRS) for the one or more RISs.

34. The method of claim 33, wherein the beam information includes:
a PRS identifier and associated RIS identifier, or
RIS orientation, or
an Azimuth and elevation of the respective PRS beam, or
a beam width of the respective PRS beam, or
a boresight direction or beamwidth uncertainty, or
a power level of one or more side lobes or a back lobe with respect to boresight,
or
a combination thereof.

35. A user equipment (UE), comprising:
a memory;
at least one transceiver; and
at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to:
receive, via the at least one transceiver, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
perform one or more location procedures based on the location assistance data.

36. The UE of claim 35, wherein the information comprises a notification of the presence of the one or more RISs in an area.

37. The UE of claim 36,
wherein the area corresponds to a cell, or
wherein the area is based on a position estimate of the UE, or

a combination thereof.

38. The UE of claim 36,
wherein the one or more RISs include multiple RISs, and
wherein the information comprises a respective RIS identifier for each of the multiple RISs.

39. The UE of claim 35,
wherein the one or more location procedures are associated with UE-based position estimation of the UE, and
wherein the information comprises a respective location associated with each of the one or more RISs.

40. The UE of claim 35, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

41. The UE of claim 40,
wherein at least one of the one or more RISs is indicated as a relay RIS, and
wherein the information further includes, with respect to the at least one RIS, an indication of a gain of RIS reflection, a group delay, or a combination thereof.

42. The UE of claim 35, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

43. The UE of claim 42,
wherein the at least one RS-P comprises at least one uplink or sidelink sounding reference signal for positioning (SRS-P) transmitted by the UE, or
wherein the at least one RS-P comprises at least one downlink or sidelink positioning reference signal (PRS) transmitted by the wireless node, or
a combination thereof.

44. The UE of claim 43,
wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node,
wherein the information comprises first quasi-colocation (QCL) information associated with the at least one downlink or sidelink PRS transmitted by the wireless node, and
wherein the information comprises second QCL information associated the at least one RS-P as reflected off of the one or more RISs.

45. The UE of claim 44, wherein a QCL source associated with the first QCL information, the second QCL information, or both, corresponds to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS).

46. The UE of claim 43,
wherein the at least one RS-P comprises the at least one PRS transmitted by the wireless node,
wherein the information comprises one or more PRS search window parameters.

47. The UE of claim 46, wherein the one or more PRS search window parameters comprise an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE.

48. The UE of claim 42, wherein the information comprises an association between the at least one RS-P and the one or more RISs.

49. The UE of claim 35, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

50. The UE of claim 49, wherein the information comprises beam information of each positioning reference signal (PRS) for the one or more RISs.

51. The UE of claim 50, wherein the beam information includes:
a PRS identifier and associated RIS identifier, or
RIS orientation, or
an Azimuth and elevation of the respective PRS beam, or
a beam width of the respective PRS beam, or
a boresight direction or beamwidth uncertainty, or
a power level of one or more side lobes or a back lobe with respect to boresight,
or
a combination thereof.

52. A network component, comprising:
a memory;
at least one transceiver; and
at least one processor communicatively coupled to the memory and the at least one transceiver, the at least one processor configured to:
determine location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
cause the at least one transceiver to transmit, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

53. The network component of claim 52, wherein the information comprises a notification of the presence of the one or more RISs in an area.

54. The network component of claim 53,
wherein the area corresponds to a cell, or
wherein the area is based on a position estimate of the UE, or
a combination thereof.

55. The network component of claim 53,
wherein the one or more RISs include multiple RISs, and

wherein the information comprises a respective RIS identifier for each of the multiple RISs.

56. The network component of claim 52,
wherein the one or more location procedures are associated with UE-based position estimation of the UE, and
wherein the information comprises a respective location associated with each of the one or more RISs.

57. The network component of claim 52, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

58. The network component of claim 57,
wherein at least one of the one or more RISs is indicated as a relay RIS, and
wherein the information further includes, with respect to the at least one RIS, an indication of a gain of RIS reflection, a group delay, or a combination thereof.

59. The network component of claim 52, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

60. The network component of claim 59,
wherein the at least one RS-P comprises at least one uplink or sidelink sounding reference signal for positioning (SRS-P) transmitted by the UE, or
wherein the at least one RS-P comprises at least one downlink or sidelink positioning reference signal (PRS) transmitted by the wireless node, or
a combination thereof.

61. The network component of claim 60,
wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node,

wherein the information comprises first quasi-colocation (QCL) information associated with the at least one downlink or sidelink PRS transmitted by the wireless node, and

wherein the information comprises second QCL information associated the at least one RS-P as reflected off of the one or more RISs.

62. The network component of claim 61, wherein a QCL source associated with the first QCL information, the second QCL information, or both, corresponds to another RS-P, a signal synchronization block (SSB), or a channel state information reference signal (CSI-RS).

63. The network component of claim 60,
wherein the at least one RS-P comprises the at least one downlink or sidelink PRS transmitted by the wireless node,
wherein the information comprises one or more PRS search window parameters.

64. The network component of claim 63, wherein the one or more PRS search window parameters comprise an expected reference signal time differential (RSTD) or an expected RSTD uncertainty associated with arrival of the at least one downlink or sidelink PRS at the UE.

65. The network component of claim 59, wherein the information comprises an association between the at least one RS-P and the one or more RISs.

66. The network component of claim 52, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

67. The network component of claim 66, wherein the information comprises beam information of each positioning reference signal (PRS) for the one or more RISs.

68. The network component of claim 67, wherein the beam information includes:

a PRS identifier and associated RIS identifier, or
RIS orientation, or
an Azimuth and elevation of the respective PRS beam, or
a beam width of the respective PRS beam, or
a boresight direction or beamwidth uncertainty, or
a power level of one or more side lobes or a back lobe with respect to boresight,
or
a combination thereof.

69. A user equipment (UE), comprising:
means for receiving, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
means for performing one or more location procedures based on the location assistance data.

70. The UE of claim 69, wherein the information comprises a notification of the presence of the one or more RISs in an area.

71. The UE of claim 69,
wherein the one or more location procedures are associated with UE-based position estimation of the UE, and
wherein the information comprises a respective location associated with each of the one or more RISs.

72. The UE of claim 69, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

73. The UE of claim 69, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

74. The UE of claim 69, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

75. A network component, comprising:
means for determining location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
means for transmitting, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

76. The network component of claim 75, wherein the information comprises a notification of the presence of the one or more RISs in an area.

77. The network component of claim 75,
wherein the one or more location procedures are associated with UE-based position estimation of the UE, and
wherein the information comprises a respective location associated with each of the one or more RISs.

78. The network component of claim 75, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

79. The network component of claim 75, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

80. The network component of claim 75, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

81. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a user equipment (UE), cause the UE to:

receive, from a network component, location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and
perform one or more location procedures based on the location assistance data.

82. The non-transitory computer-readable medium of claim 81, wherein the information comprises a notification of the presence of the one or more RISs in an area.

83. The non-transitory computer-readable medium of claim 81,
wherein the one or more location procedures are associated with UE-based position estimation of the UE, and
wherein the information comprises a respective location associated with each of the one or more RISs.

84. The non-transitory computer-readable medium of claim 81, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

85. The non-transitory computer-readable medium of claim 81, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

86. The non-transitory computer-readable medium of claim 81, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

87. A non-transitory computer-readable medium storing computer-executable instructions that, when executed by a network component, cause the network component to:

determine location assistance data comprising information associated with one or more reconfigurable intelligent surfaces (RISs); and

transmit, to a user equipment (UE), the location assistance data to facilitate one or more location procedures based on the location assistance data.

88. The non-transitory computer-readable medium of claim 87, wherein the information comprises a notification of the presence of the one or more RISs in an area.

89. The non-transitory computer-readable medium of claim 87, wherein the one or more location procedures are associated with UE-based position estimation of the UE, and

wherein the information comprises a respective location associated with each of the one or more RISs.

90. The non-transitory computer-readable medium of claim 87, wherein, for each of the one or more RISs, the information comprises an indication of whether the respective RIS is a passive RIS or a relay RIS.

91. The non-transitory computer-readable medium of claim 87, wherein the one or more location procedures are associated with at least one reference signal for positioning (RS-P) communicated between the UE and a wireless node via reflection off of the one or more RISs.

92. The non-transitory computer-readable medium of claim 87, wherein the one or more one or more location procedures comprises a downlink angle of departure (DL-AoD) positioning session of the UE.

1/16

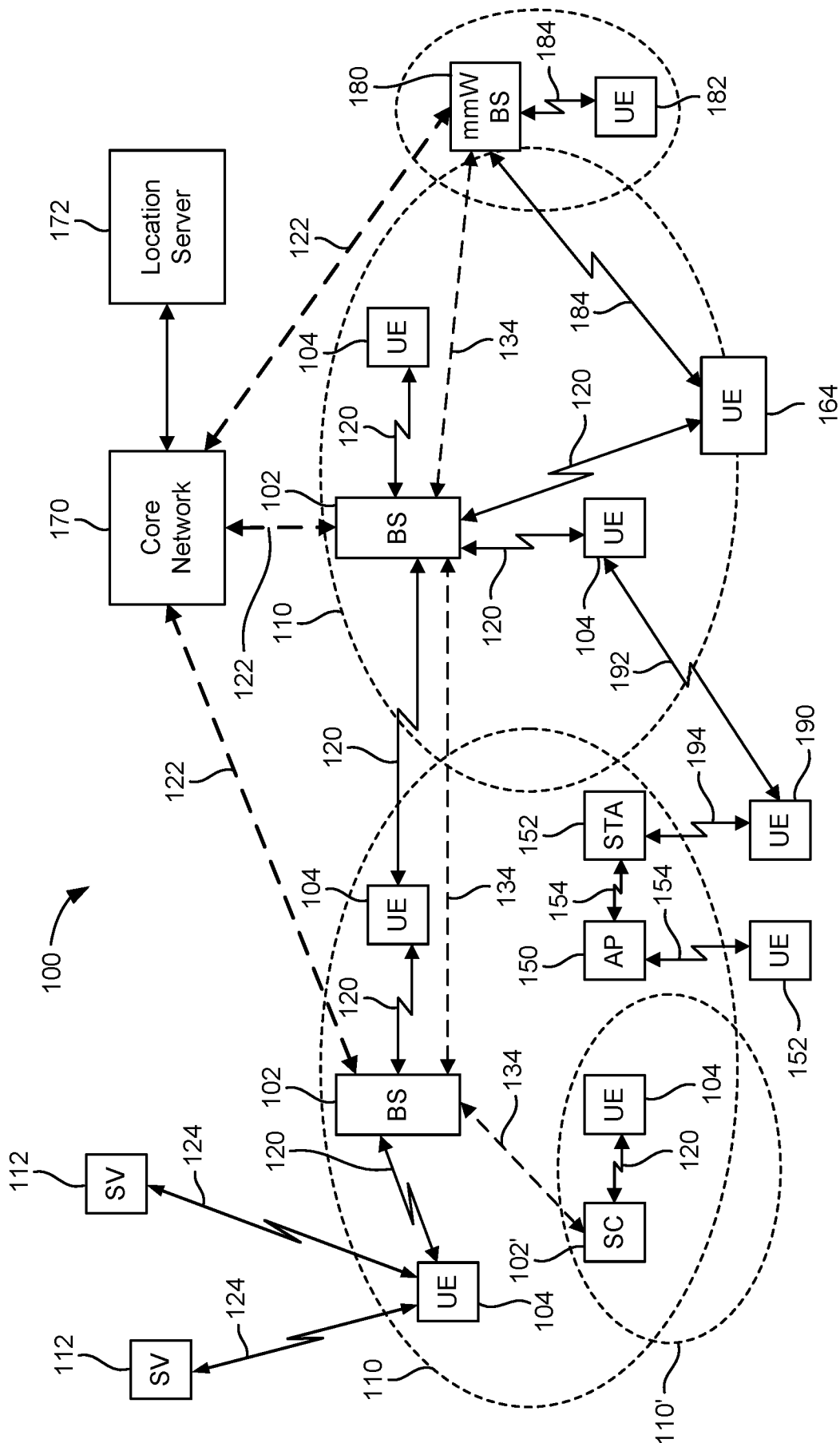


FIG. 1

2/16

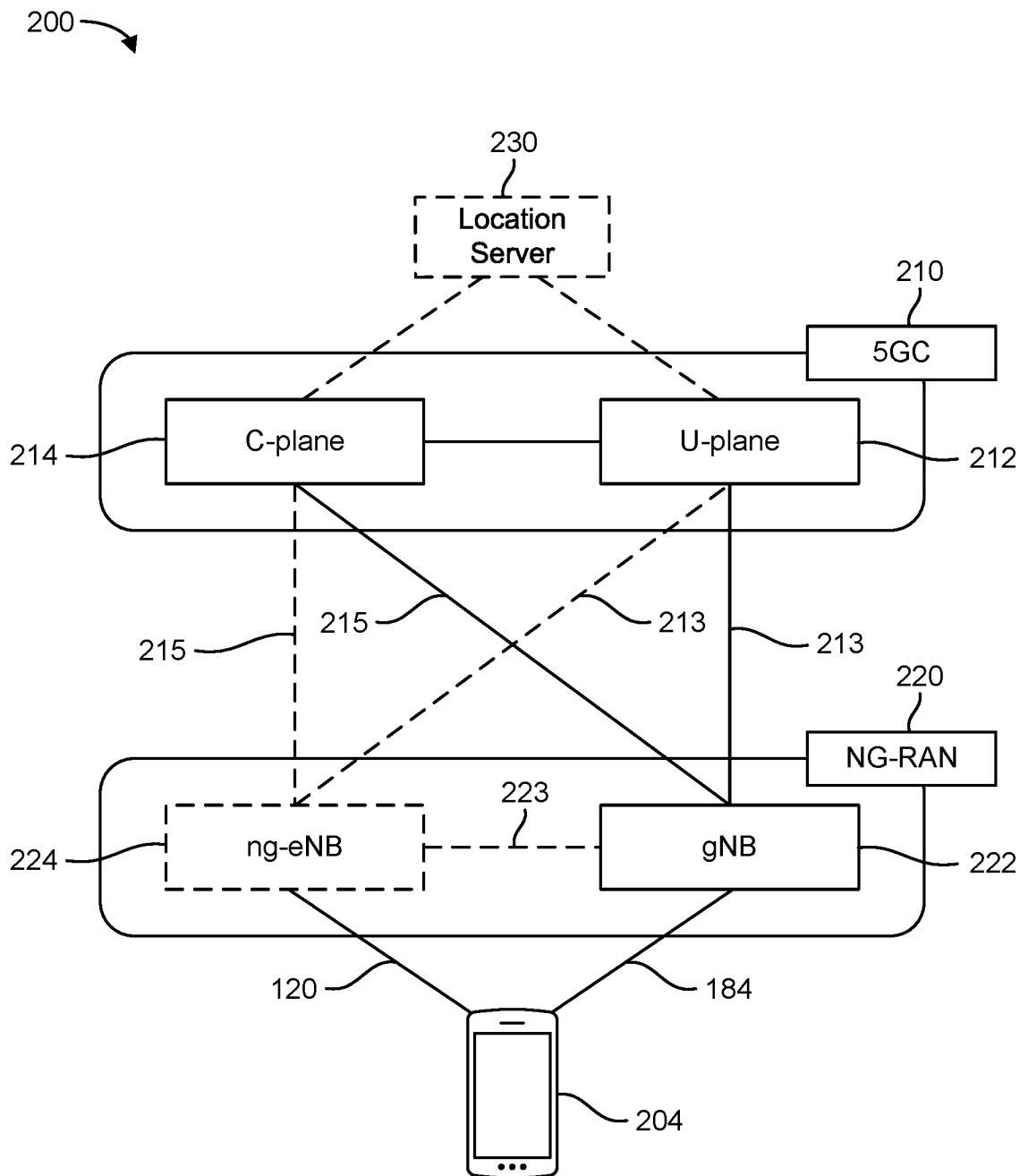


FIG. 2A

3/16

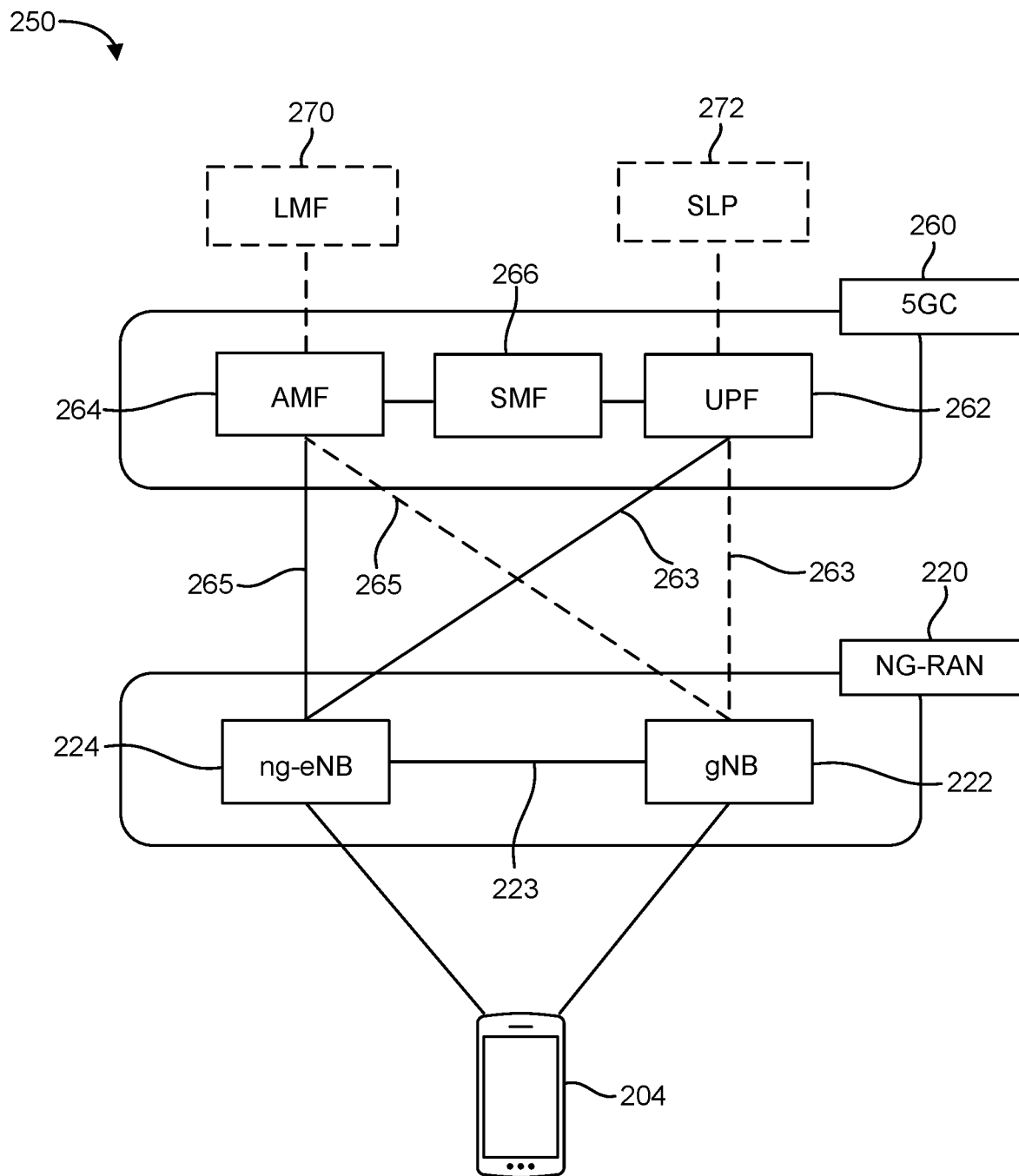


FIG. 2B

4/16

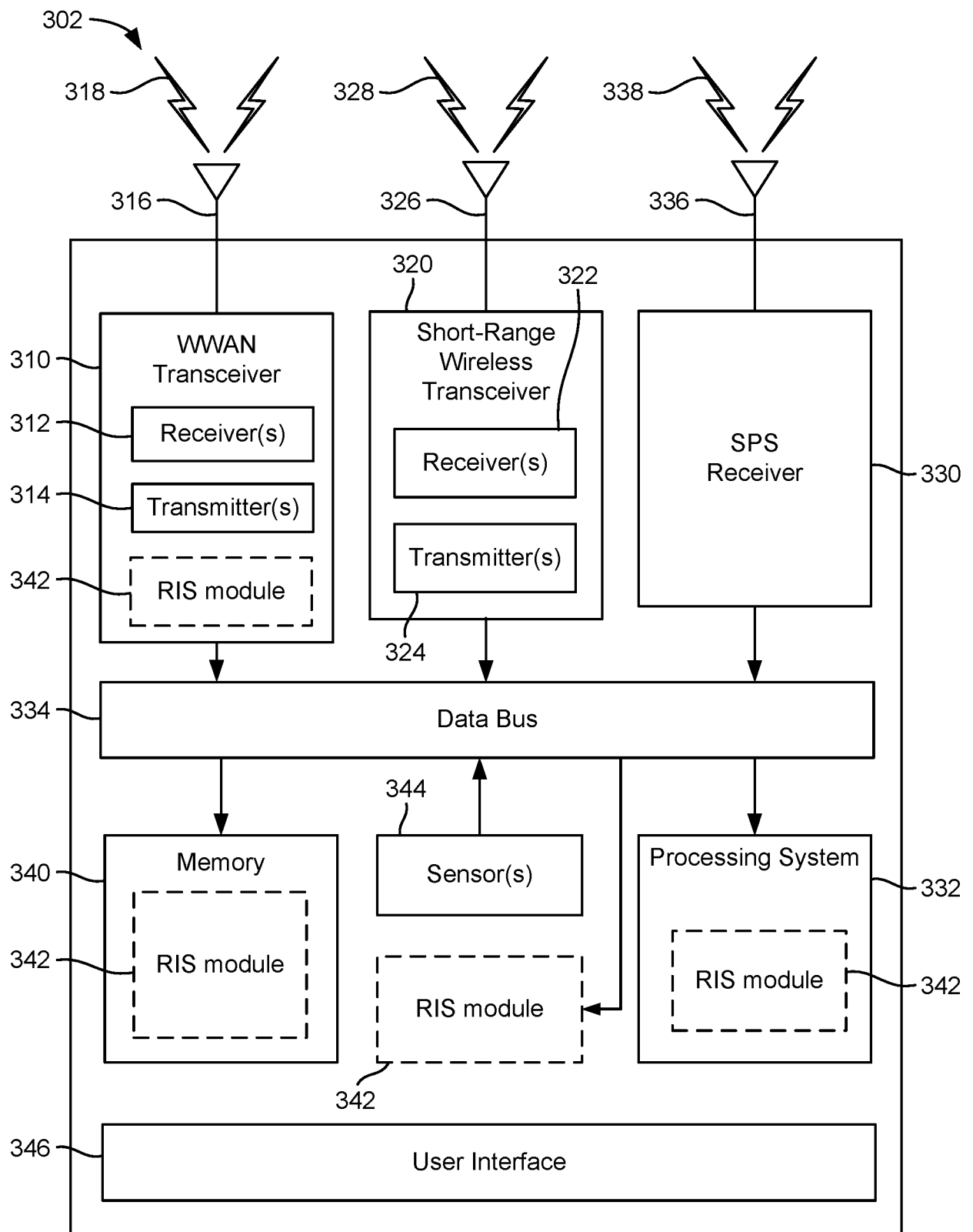


FIG. 3A

5/16

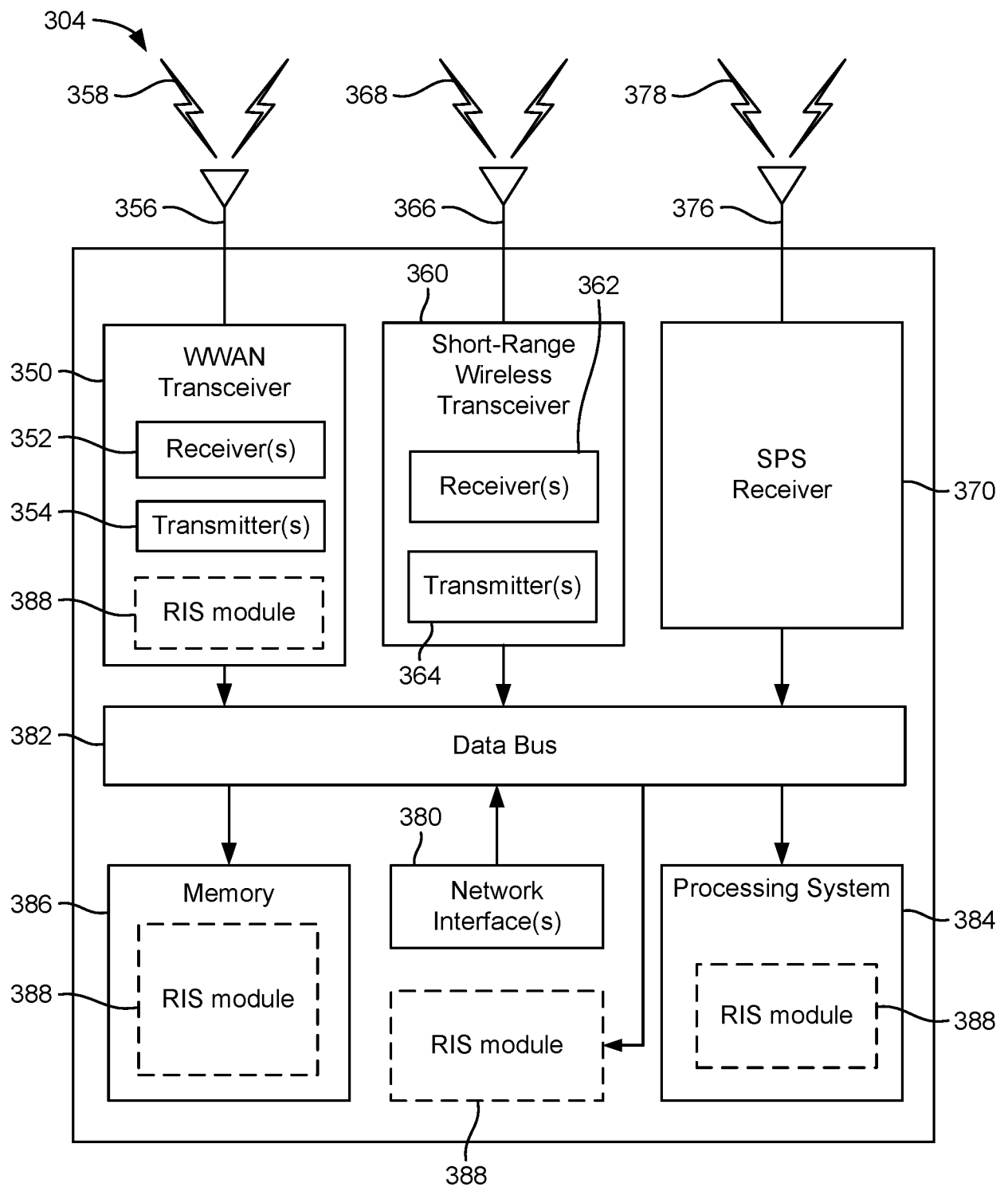


FIG. 3B

6/16

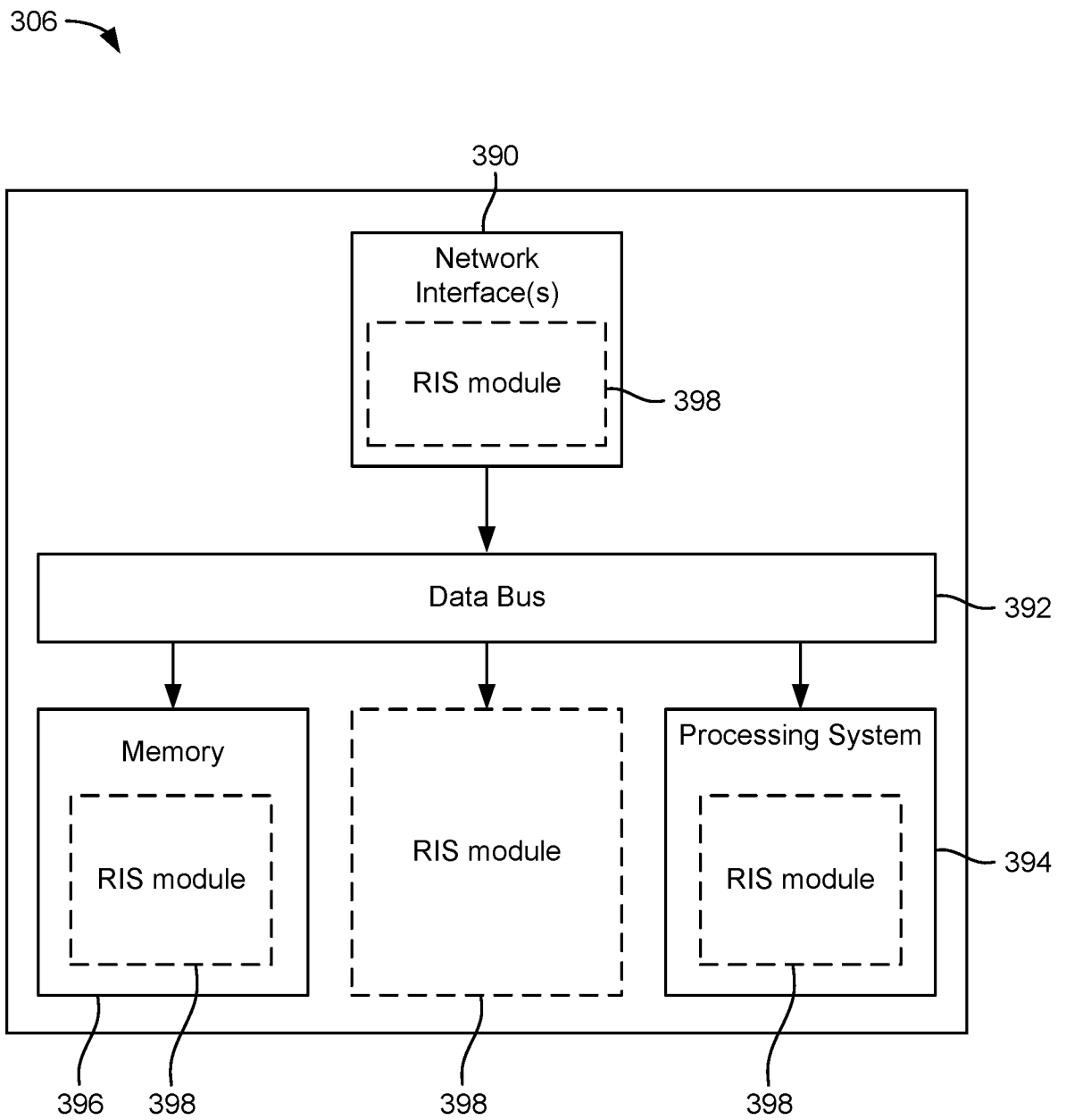


FIG. 3C

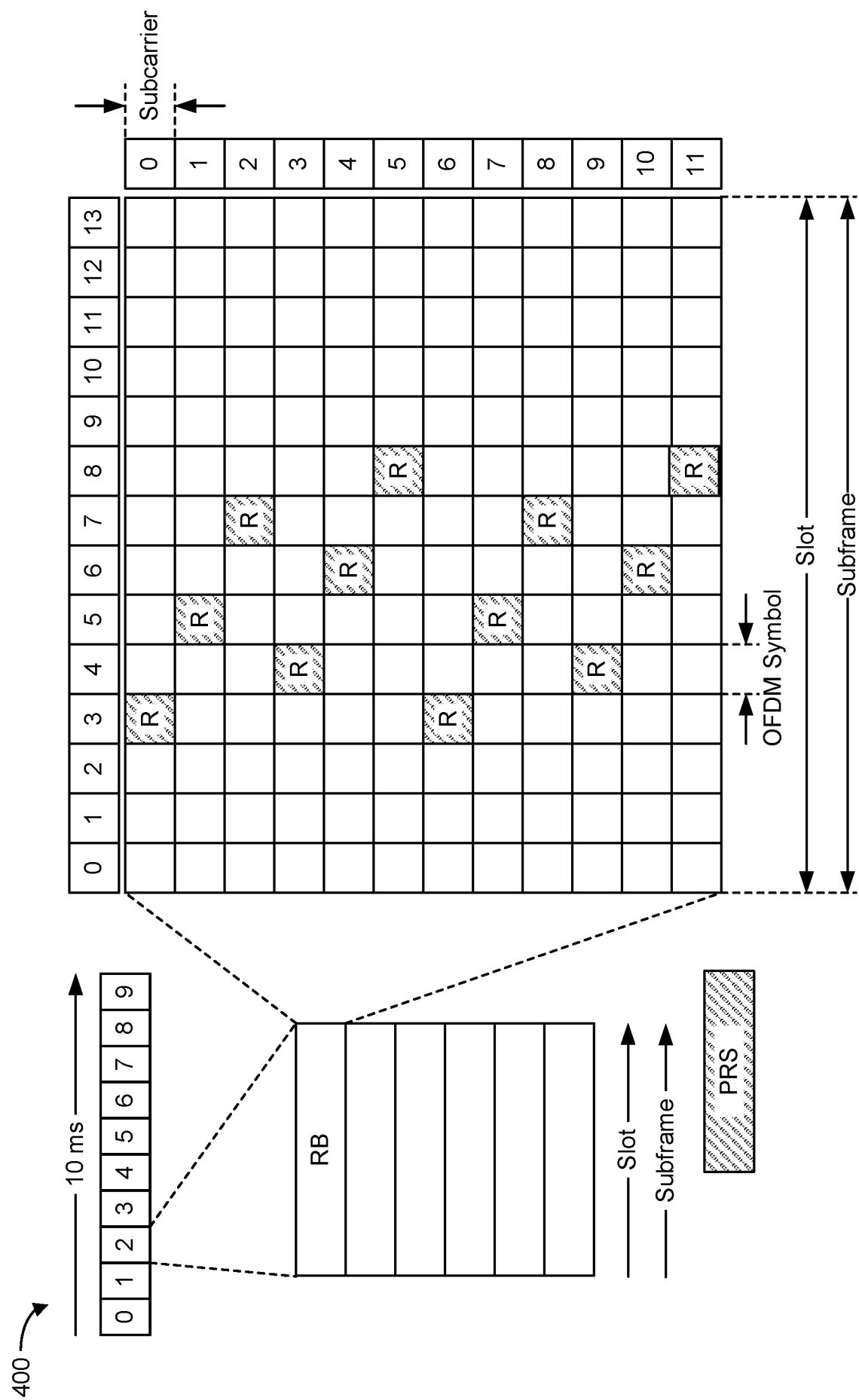


FIG. 4A

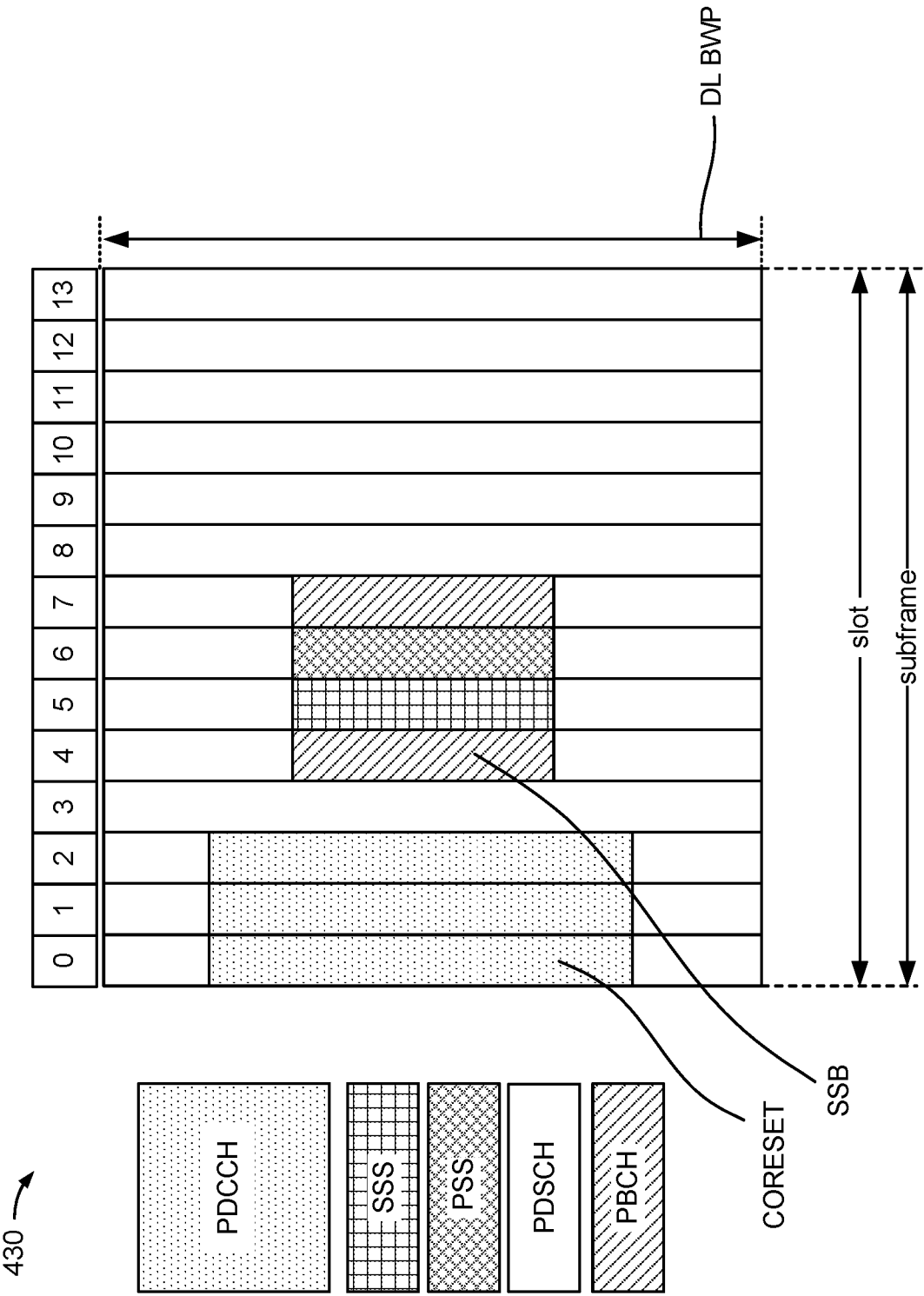


FIG. 4B

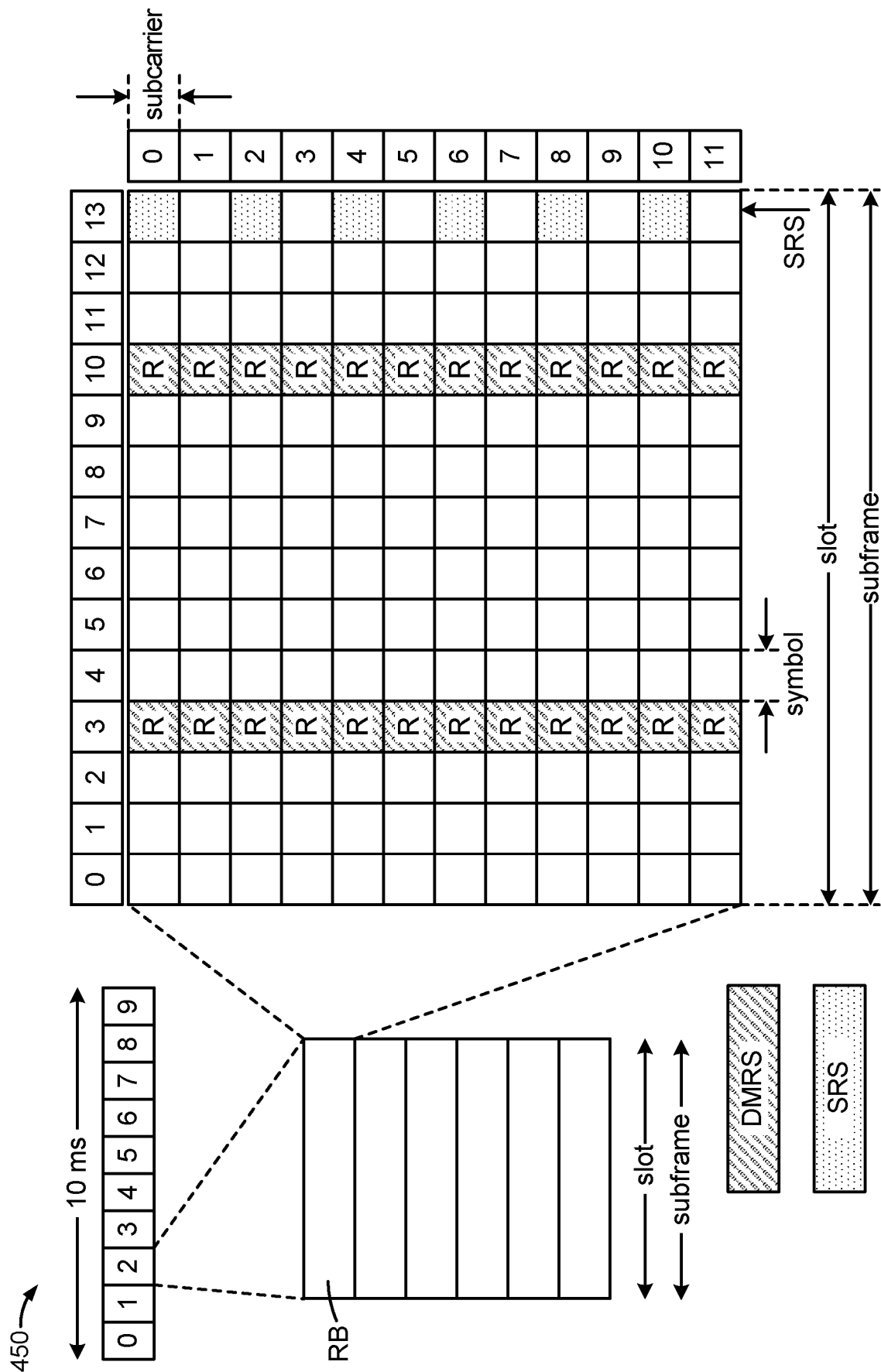


FIG. 4C

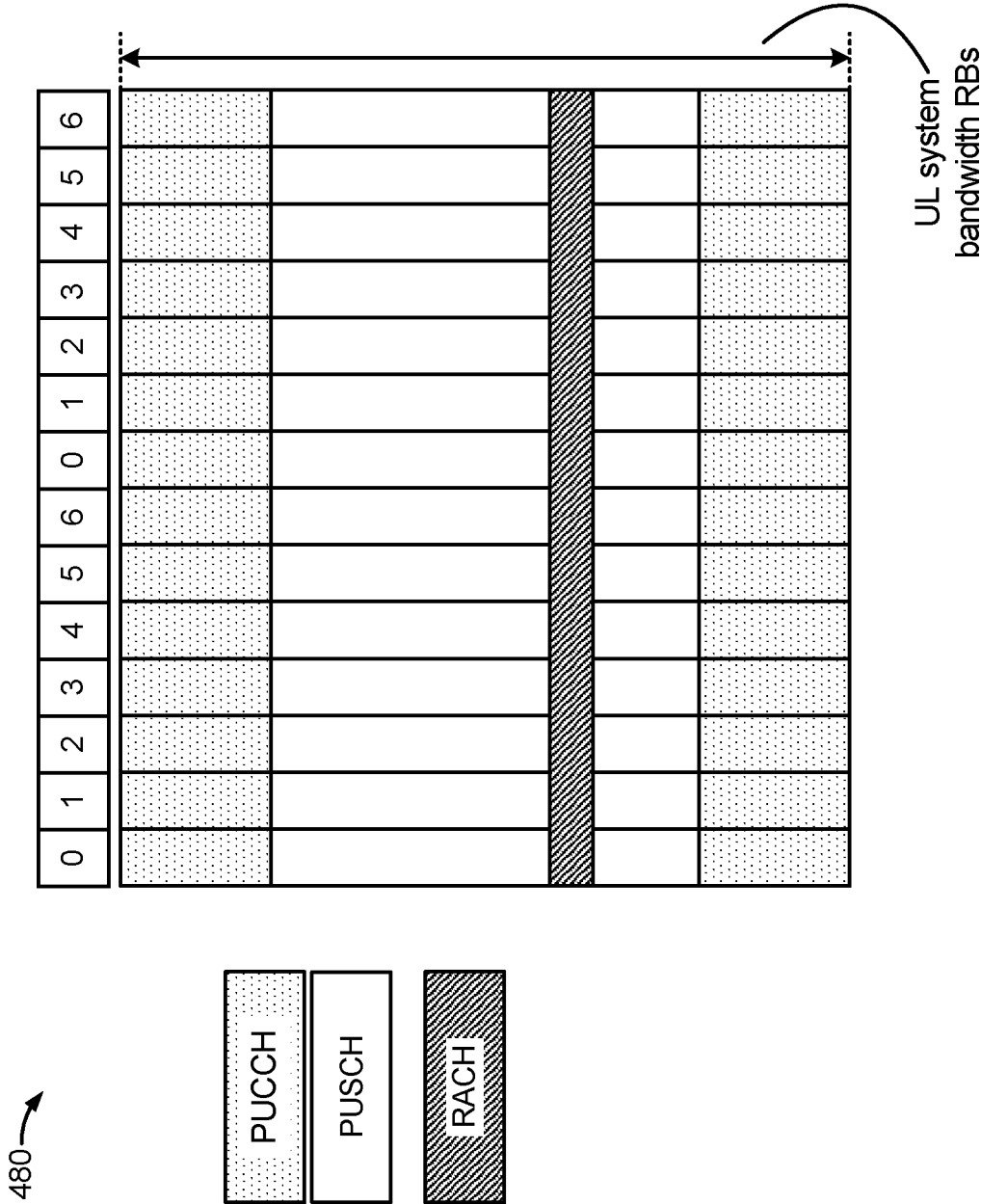


FIG. 4D

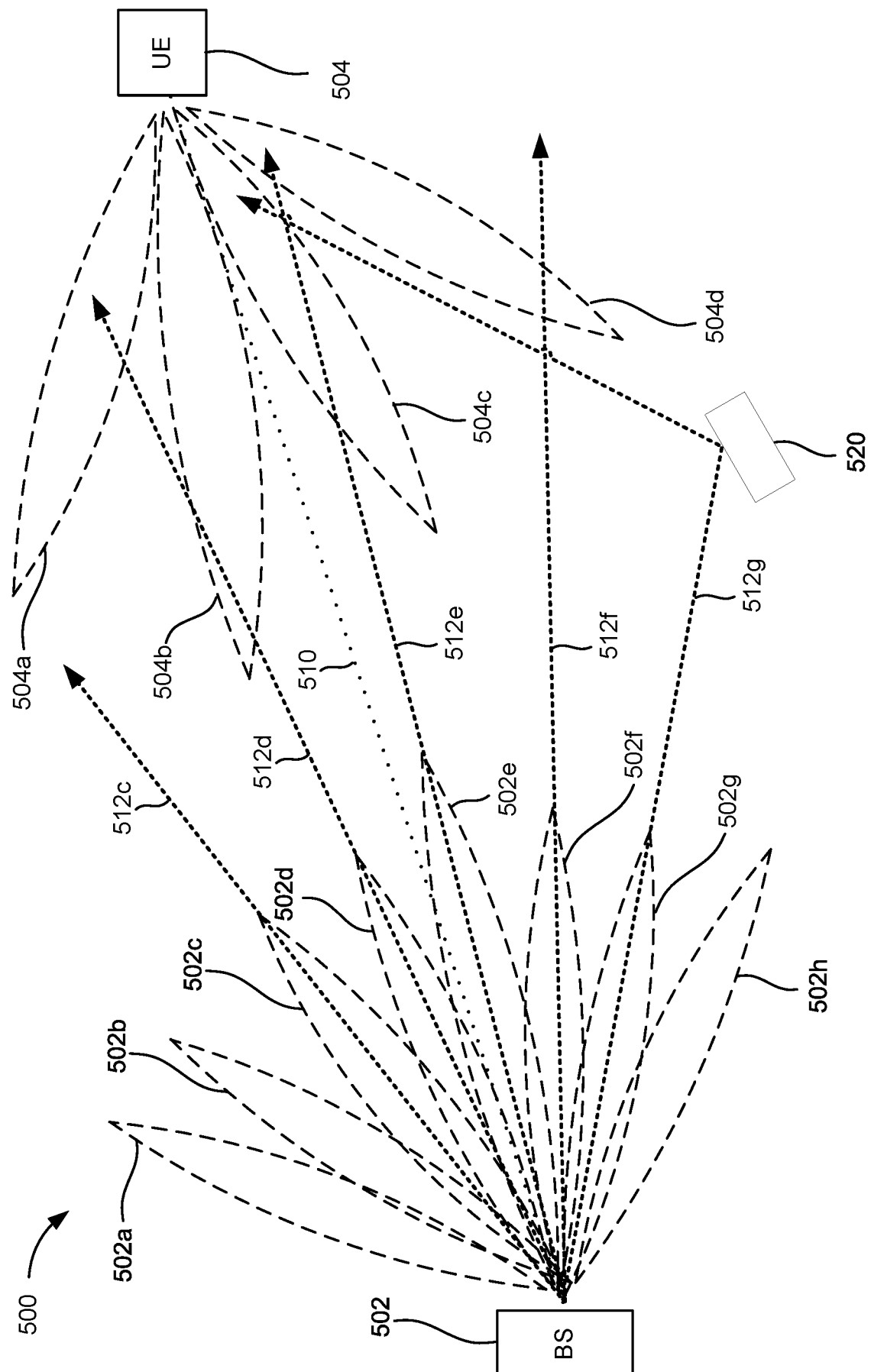


FIG. 5

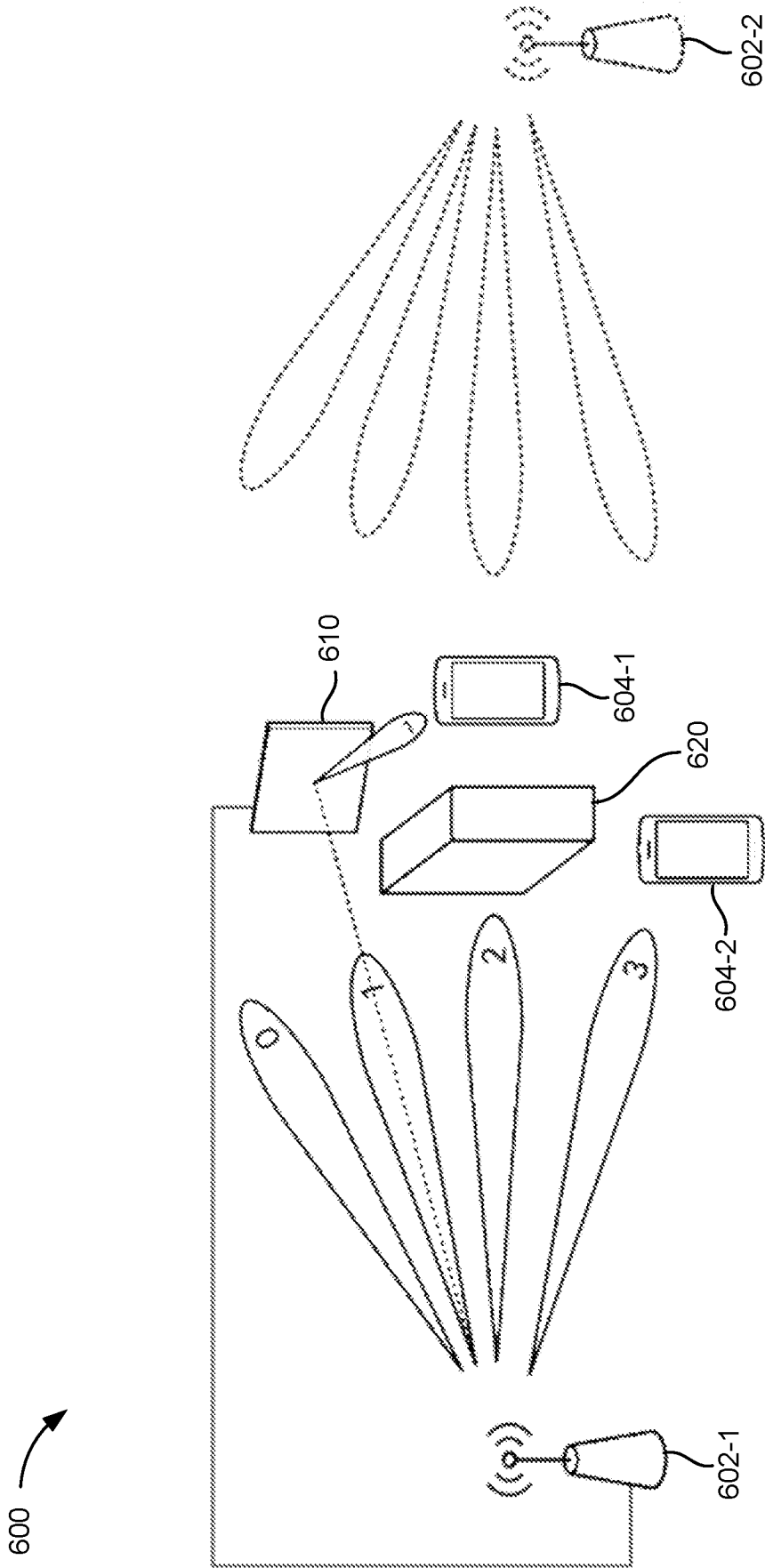


FIG. 6

13/16

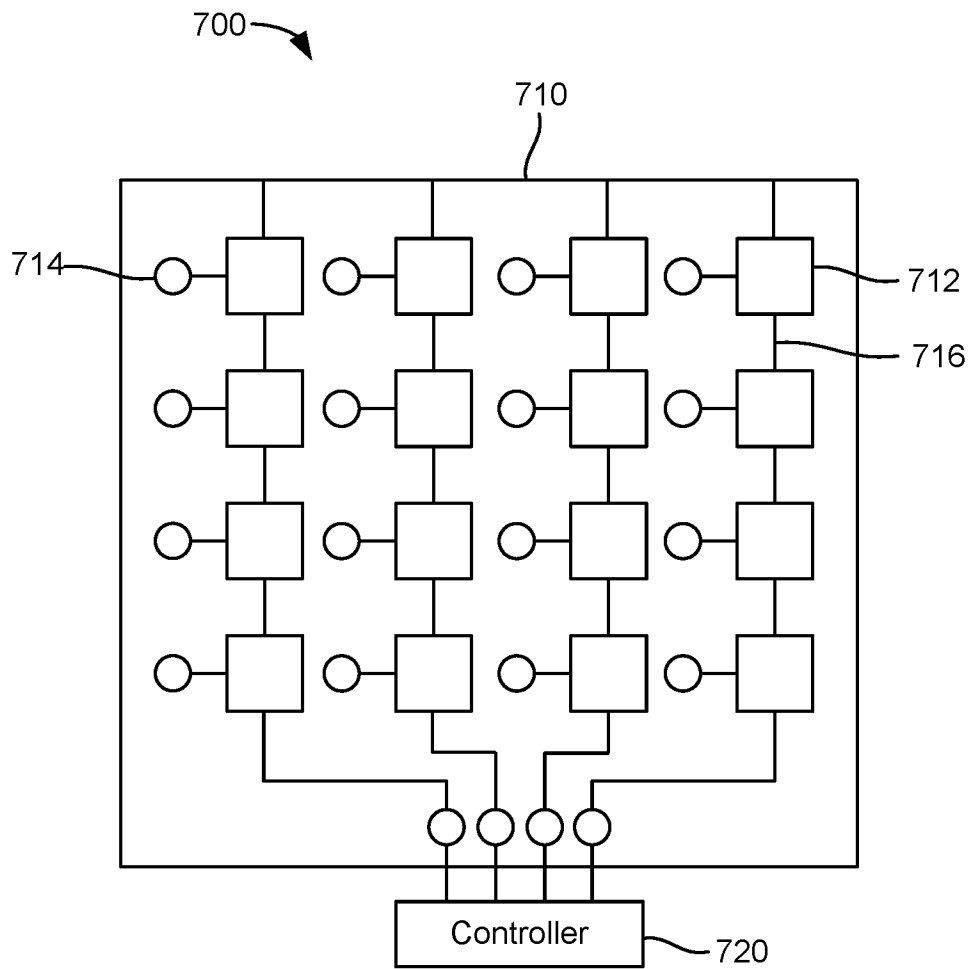
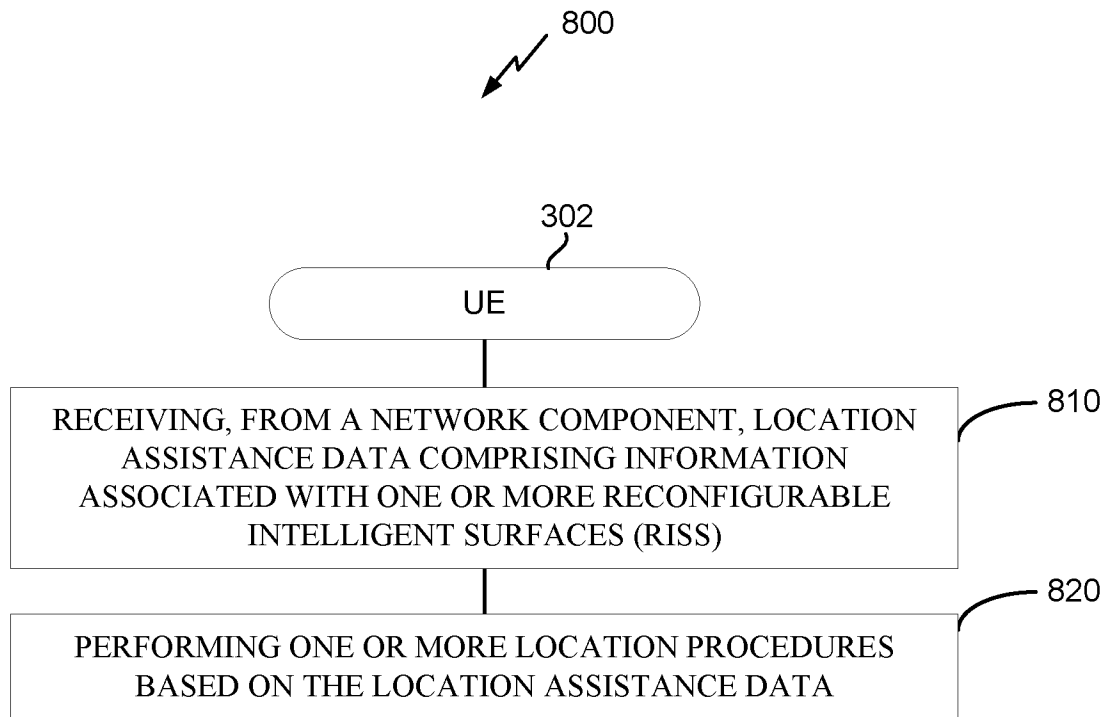
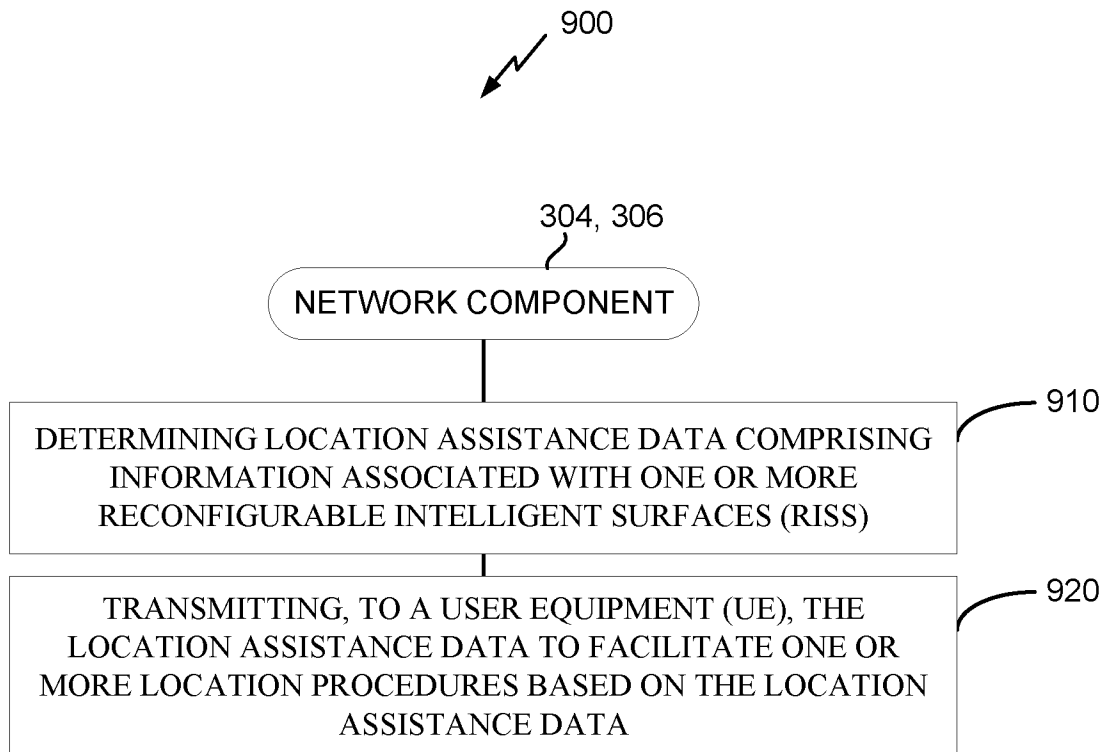


FIG. 7

14/16

**FIG. 8**

15/16

**FIG. 9**

16/16

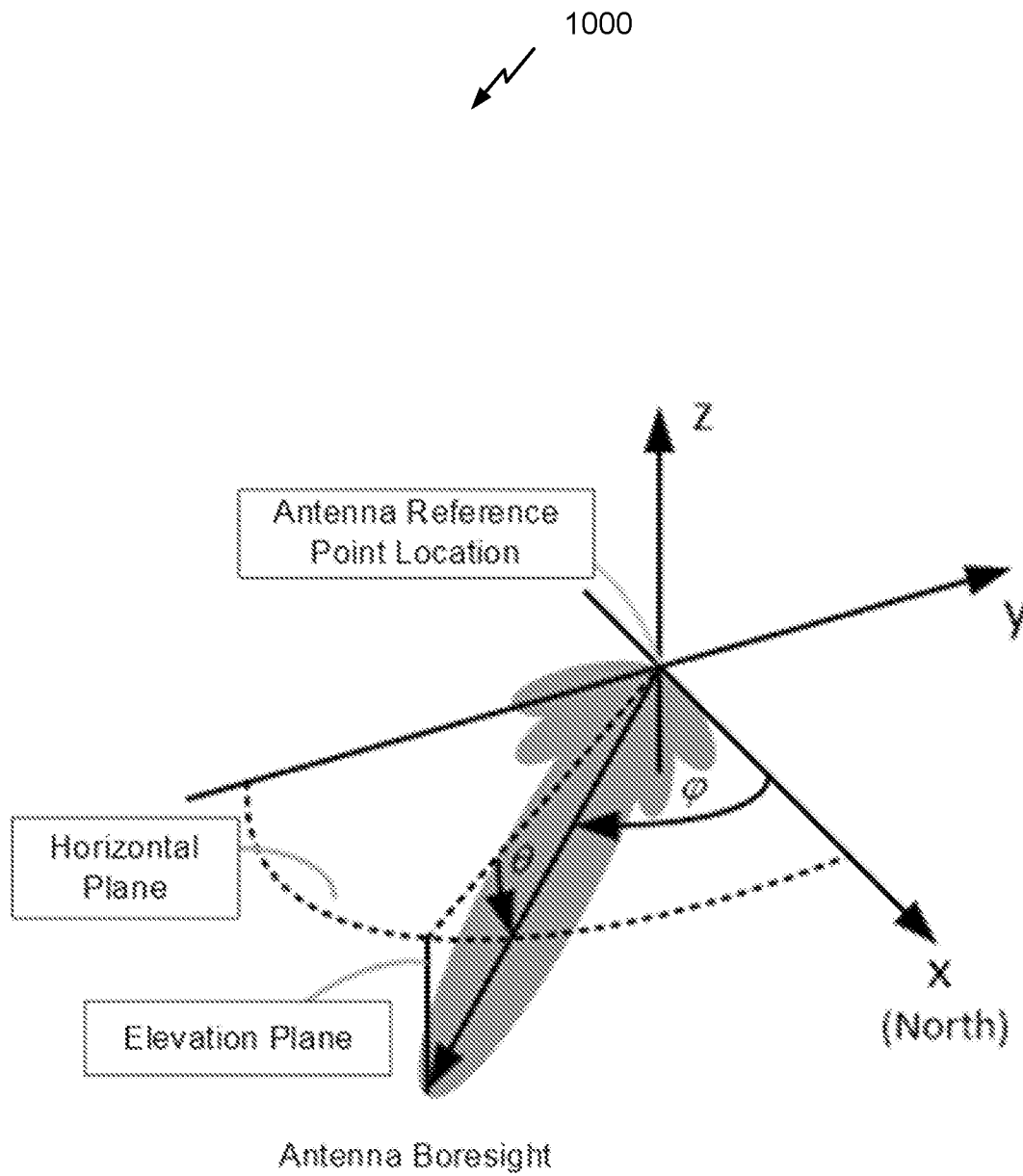


FIG. 10