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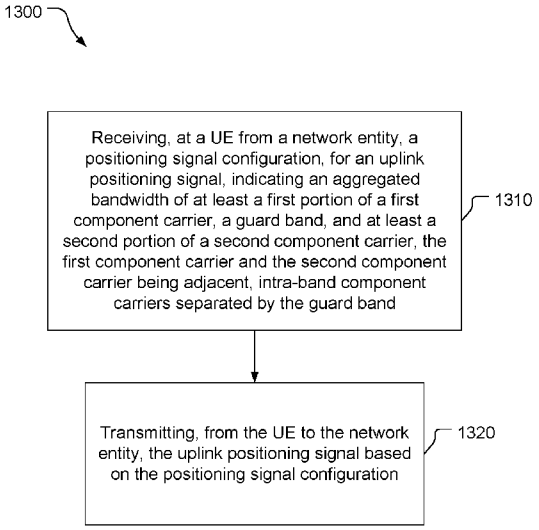


FIG. 13

(57) Abstract: A positioning signal transmission method includes: receiving, at a UE from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and transmitting, from the UE to the network entity, the uplink positioning signal based on the positioning signal configuration.

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EXPANDED-FREQUENCY SOUNDING REFERENCE SIGNALS FOR POSITIONING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Greek Patent Application No. 20230100030, filed January 16, 2023, entitled "EXPANDED-FREQUENCY SOUNDING REFERENCE SIGNALS FOR POSITIONING," which is assigned to the assignee hereof, and the entire contents of which are hereby incorporated herein by reference for all purposes.

BACKGROUND

[0002] 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, a fourth-generation (4G) service (e.g., Long Term Evolution (LTE) or WiMax), a fifth-generation (5G) service, etc. 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), Orthogonal Frequency Division Multiple Access (OFDMA), Time Division Multiple Access (TDMA), the Global System for Mobile access (GSM) variation of TDMA, etc.

[0003] A fifth generation (5G) mobile standard 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.

[0004] Obtaining the locations of mobile devices that are accessing a wireless network may be useful for many applications including, for example, emergency calls, personal navigation, asset tracking, locating a friend or family member, etc. Existing positioning methods include methods based on measuring radio signals transmitted from a variety of devices or entities including satellite vehicles (SVs) and terrestrial radio sources in a wireless network such as base stations and access points.

SUMMARY

[0005] An example user equipment (UE) includes: a transceiver; a memory; and a processor communicatively coupled to the transceiver and the memory and configured to: receive, via the transceiver from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and transmit, via the transceiver to the network entity, the uplink positioning signal based on the positioning signal configuration.

[0006] An example positioning signal transmission method includes: receiving, at a UE from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and transmitting, from the UE to the network entity, the uplink positioning signal based on the positioning signal configuration.

[0007] Another example UE includes: means for receiving, from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers

separated by the guard band; and means for transmitting, to the network entity, the uplink positioning signal based on the positioning signal configuration.

[0008] An example non-transitory, processor-readable storage medium includes processor-readable instructions to cause a processor of a UE to: receive, from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band: and transmit, to the network entity, the uplink positioning signal based on the positioning signal configuration.

[0009] An example network entity includes: a transmitter; a memory; and a processor communicatively coupled to the transmitter and the memory and configured to: determine an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and transmit, via the transmitter to a user equipment, the uplink positioning signal configuration.

[0010] An example positioning signal configuration providing method includes: determining, at a network entity, an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and transmitting, from the network entity to a user equipment, the uplink positioning signal configuration.

[0011] Another example network entity includes: means for determining an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and means for transmitting, to a user equipment, the uplink positioning signal configuration.

[0012] Another example non-transitory, processor-readable storage medium includes processor-readable instructions to cause a processor of a network entity to: determine an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and transmit, to a user equipment, the uplink positioning signal configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a simplified diagram of an example wireless communications system.

[0014] FIG. 2 is a block diagram of components of an example user equipment shown in FIG. 1.

[0015] FIG. 3 is a block diagram of components of an example transmission/reception point shown in FIG. 1.

[0016] FIG. 4 is a block diagram of components of an example server shown in FIG. 1.

[0017] FIG. 5 is a block diagram of an example user equipment.

[0018] FIG. 6 is a block diagram of an example network entity.

[0019] FIG. 7 is a frequency diagram of adjacent component carriers separated by a guard band.

[0020] FIG. 8 is a frequency diagram of adjacent component carrier bandwidths, a single positioning signal configuration bandwidth including the adjacent component carrier bandwidths, and a partial positioning signal transmission bandwidth.

[0021] FIG. 9 is a frequency diagram of a component carrier bandwidth, a guard band, an extended positioning signal configuration bandwidth, and a truncated positioning signal transmission bandwidth.

[0022] FIG. 10 is a frequency diagram of adjacent component carrier bandwidths, and per-component positioning signal configuration bandwidths.

[0023] FIG. 11 is a time and frequency diagram of sounded tones of adjacent component carriers and a guard band carrying one or more positioning signals.

[0024] FIG. 12 is a signal and processing flow diagram for determining position information based on an uplink positioning signal based on a configuration corresponding to frequencies inside and outside of a component carrier bandwidth.

[0025] FIG. 13 is a block flow diagram of a positioning signal transmission method.

[0026] FIG. 14 is a block flow diagram of a positioning signal configuration providing method.

[0027] FIG. 15 is a block flow diagram of another positioning signal configuration providing method.

DETAILED DESCRIPTION

[0028] Techniques are discussed herein for providing a configuration for sounding reference signals for positioning (SRS for positioning, SRS-pos), also called uplink positioning reference signals (UL-PRS) and transmitting UL-PRS according to the provided configuration. The provided configuration corresponds to frequencies both inside and outside of a first carrier bandwidth. For example, the configuration may correspond to frequencies in the first carrier bandwidth and one or more frequencies of a guard band separating the first carrier bandwidth and a second carrier bandwidth, with the first and second carrier bandwidths being adjacent carrier bandwidths (being consecutive in frequency, without any other carrier bandwidth between the adjacent carrier bandwidths although there may be a guard band between the adjacent carrier bandwidths). The guard band may span higher or lower frequencies than the first carrier bandwidth. If the guard band spans frequencies lower than the first carrier bandwidth, then an indication may be provided as to a starting frequency for the UL-PRS. As another example, the configuration may correspond to frequencies in the first carrier bandwidth and one or more frequencies in the second carrier bandwidth, with the first and second carrier bandwidths being adjacent carrier bandwidths. A user equipment (UE) may use the provided configuration to transmit UL-PRS to the network entity. The UE may send a partial or truncated UL-PRS transmission spanning less bandwidth than indicated by the configuration. A comb pattern may be continuous for the UL-PRS, e.g., across the first carrier bandwidth, the guard band (if used to transmit the UL-PRS), and the second carrier bandwidth. Other configurations, however, may be used.

[0029] Items and/or techniques described herein may provide one or more of the following capabilities, as well as other capabilities not mentioned. Positioning accuracy may be improved, e.g., by increasing a bandwidth of a positioning signal, e.g., beyond a carrier bandwidth. Signal processing complexity at a UL-PRS receiver (e.g., gNB) may

be reduced, e.g., by transmitting contiguous UL-PRS tones across adjacent carrier bandwidths. Other capabilities may be provided and not every implementation according to the disclosure must provide any, let alone all, of the capabilities discussed.

[0030] Obtaining the locations of mobile devices that are accessing a wireless network may be useful for many applications including, for example, emergency calls, personal navigation, consumer asset tracking, locating a friend or family member, etc. Existing positioning methods include methods based on measuring radio signals transmitted from a variety of devices or entities including satellite vehicles (SVs) and terrestrial radio sources in a wireless network such as base stations and access points. It is expected that standardization for the 5G wireless networks will include support for various positioning methods, which may utilize reference signals transmitted by base stations in a manner similar to which LTE wireless networks currently utilize Positioning Reference Signals (PRS) and/or Cell-specific Reference Signals (CRS) for position determination.

[0031] The description herein may refer to sequences of actions to be performed, for example, by elements of a computing device. Various actions described herein can be performed by specific circuits (e.g., an application specific integrated circuit (ASIC)), by program instructions being executed by one or more processors, or by a combination of both. Sequences of actions described herein may be embodied within a non-transitory computer-readable medium having stored thereon a corresponding set of computer instructions that upon execution would cause an associated processor to perform the functionality described herein. Thus, the various examples described herein may be embodied in a number of different forms, all of which are within the scope of the disclosure, including claimed subject matter.

[0032] As used herein, the terms "user equipment" (UE) and "base station" are not specific to or otherwise limited to any particular Radio Access Technology (RAT), unless otherwise noted. In general, such UEs may be any wireless communication device (e.g., a mobile phone, router, tablet computer, laptop computer, consumer asset tracking device, 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 terminal," a "mobile station," a "mobile device," 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, WiFi networks (e.g., based on IEEE (Institute of Electrical and Electronics Engineers) 802.11, etc.) and so on.

[0033] A base station may operate according to one of several RATs in communication with UEs depending on the network in which it is deployed. Examples of a base station include an Access Point (AP), a Network Node, a NodeB, an evolved NodeB (eNB), or a general Node B (gNodeB, gNB). In addition, 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.

[0034] UEs may be embodied by any of a number of types of devices including but not limited to printed circuit (PC) cards, compact flash devices, external or internal modems, wireless or wireline phones, smartphones, tablets, consumer asset tracking devices, asset tags, and so on. A communication link through which UEs can send signals to a RAN is called an uplink channel (e.g., a reverse traffic channel, a reverse control channel, an access channel, etc.). A communication link through which the RAN can send signals to UEs is called a downlink 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.

[0035] As used herein, the term "cell" or "sector" may correspond to one of a plurality of cells of a base station, or to the base station itself, depending on the context. The term "cell" may refer to a logical communication entity used for communication with a base station (for example, over a carrier), and may be associated with an identifier for distinguishing neighboring cells (for example, a physical cell identifier (PCID), a virtual cell identifier (VCID)) operating via the same or a different carrier. In some examples, a carrier may support multiple cells, and different cells may be configured according to different protocol types (for example, machine-type communication (MTC), narrowband Internet-of-Things (NB-IoT), enhanced mobile broadband (eMBB), or others) that may provide access for different types of devices. In some examples, the

term "cell" may refer to a portion of a geographic coverage area (for example, a sector) over which the logical entity operates.

[0036] Referring to FIG. 1, an example of a communication system 100 includes a UE 105, a UE 106, a Radio Access Network (RAN), here a Fifth Generation (5G) Next Generation (NG) RAN (NG-RAN) 135, a 5G Core Network (5GC) 140, and a server 150. The UE 105 and/or the UE 106 may be, e.g., an IoT device, a location tracker device, a cellular telephone, a vehicle (e.g., a car, a truck, a bus, a boat, etc.), or another device. A 5G network may also be referred to as a New Radio (NR) network; NG-RAN 135 may be referred to as a 5G RAN or as an NR RAN; and 5GC 140 may be referred to as an NG Core network (NGC). Standardization of an NG-RAN and 5GC is ongoing in the 3rd Generation Partnership Project (3GPP). Accordingly, the NG-RAN 135 and the 5GC 140 may conform to current or future standards for 5G support from 3GPP. The NG-RAN 135 may be another type of RAN, e.g., a 3G RAN, a 4G Long Term Evolution (LTE) RAN, etc. The UE 106 may be configured and coupled similarly to the UE 105 to send and/or receive signals to/from similar other entities in the system 100, but such signaling is not indicated in FIG. 1 for the sake of simplicity of the figure. Similarly, the discussion focuses on the UE 105 for the sake of simplicity. The communication system 100 may utilize information from a constellation 185 of satellite vehicles (SVs) 190, 191, 192, 193 for a Satellite Positioning System (SPS) (e.g., a Global Navigation Satellite System (GNSS)) like the Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS), Galileo, or Beidou or some other local or regional SPS such as the Indian Regional Navigational Satellite System (IRNSS), the European Geostationary Navigation Overlay Service (EGNOS), or the Wide Area Augmentation System (WAAS). Additional components of the communication system 100 are described below. The communication system 100 may include additional or alternative components.

[0037] As shown in FIG. 1, the NG-RAN 135 includes NR nodeBs (gNBs) 110a, 110b, and a next generation eNodeB (ng-eNB) 114, and the 5GC 140 includes an Access and Mobility Management Function (AMF) 115, a Session Management Function (SMF) 117, a Location Management Function (LMF) 120, and a Gateway Mobile Location Center (GMLC) 125. The gNBs 110a, 110b and the ng-eNB 114 are communicatively coupled to each other, are each configured to bi-directionally wirelessly communicate with the UE 105, and are each communicatively coupled to, and configured to bi-

directionally communicate with, the AMF 115. The gNBs 110a, 110b, and the ng-eNB 114 may be referred to as base stations (BSs). The AMF 115, the SMF 117, the LMF 120, and the GMLC 125 are communicatively coupled to each other, and the GMLC is communicatively coupled to an external client 130. The SMF 117 may serve as an initial contact point of a Service Control Function (SCF) (not shown) to create, control, and delete media sessions. Base stations such as the gNBs 110a, 110b and/or the ng-eNB 114 may be a macro cell (e.g., a high-power cellular base station), or a small cell (e.g., a low-power cellular base station), or an access point (e.g., a short-range base station configured to communicate with short-range technology such as WiFi, WiFi-Direct (WiFi-D), Bluetooth®, Bluetooth®-low energy (BLE), Zigbee, etc. One or more base stations, e.g., one or more of the gNBs 110a, 110b and/or the ng-eNB 114 may be configured to communicate with the UE 105 via multiple carriers. Each of the gNBs 110a, 110b and/or the ng-eNB 114 may provide communication coverage for a respective geographic region, e.g., a cell. Each cell may be partitioned into multiple sectors as a function of the base station antennas.

[0038] FIG. 1 provides a generalized illustration of various components, any or all of which may be utilized as appropriate, and each of which may be duplicated or omitted as necessary. Specifically, although one UE 105 is illustrated, many UEs (e.g., hundreds, thousands, millions, etc.) may be utilized in the communication system 100. Similarly, the communication system 100 may include a larger (or smaller) number of SVs (i.e., more or fewer than the four SVs 190-193 shown), gNBs 110a, 110b, ng-eNBs 114, AMFs 115, external clients 130, and/or other components. The illustrated connections that connect the various components in the communication system 100 include data and signaling connections which may include additional (intermediary) components, direct or indirect physical and/or wireless connections, and/or additional networks. Furthermore, components may be rearranged, combined, separated, substituted, and/or omitted, depending on desired functionality.

[0039] While FIG. 1 illustrates a 5G-based network, similar network implementations and configurations may be used for other communication technologies, such as 3G, Long Term Evolution (LTE), etc. Implementations described herein (be they for 5G technology and/or for one or more other communication technologies and/or protocols) may be used to transmit (or broadcast) directional synchronization signals, receive and measure directional signals at UEs (e.g., the UE 105) and/or provide location assistance

to the UE 105 (via the GMLC 125 or other location server) and/or compute a location for the UE 105 at a location-capable device such as the UE 105, the gNB 110a, 110b, or the LMF 120 based on measurement quantities received at the UE 105 for such directionally-transmitted signals. The gateway mobile location center (GMLC) 125, the location management function (LMF) 120, the access and mobility management function (AMF) 115, the SMF 117, the ng-eNB (eNodeB) 114 and the gNBs (gNodeBs) 110a, 110b are examples and may, in various embodiments, be replaced by or include various other location server functionality and/or base station functionality respectively.

[0040] The system 100 is capable of wireless communication in that components of the system 100 can communicate with one another (at least some times using wireless connections) directly or indirectly, e.g., via the gNBs 110a, 110b, the ng-eNB 114, and/or the 5GC 140 (and/or one or more other devices not shown, such as one or more other base transceiver stations). For indirect communications, the communications may be altered during transmission from one entity to another, e.g., to alter header information of data packets, to change format, etc. The UE 105 may include multiple UEs and may be a mobile wireless communication device, but may communicate wirelessly and via wired connections. The UE 105 may be any of a variety of devices, e.g., a smartphone, a tablet computer, a vehicle-based device, etc., but these are examples as the UE 105 is not required to be any of these configurations, and other configurations of UEs may be used. Other UEs may include wearable devices (e.g., smart watches, smart jewelry, smart glasses or headsets, etc.). Still other UEs may be used, whether currently existing or developed in the future. Further, other wireless devices (whether mobile or not) may be implemented within the system 100 and may communicate with each other and/or with the UE 105, the gNBs 110a, 110b, the ng-eNB 114, the 5GC 140, and/or the external client 130. For example, such other devices may include internet of thing (IoT) devices, medical devices, home entertainment and/or automation devices, etc. The 5GC 140 may communicate with the external client 130 (e.g., a computer system), e.g., to allow the external client 130 to request and/or receive location information regarding the UE 105 (e.g., via the GMLC 125).

[0041] The UE 105 or other devices may be configured to communicate in various networks and/or for various purposes and/or using various technologies (e.g., 5G, Wi-Fi communication, multiple frequencies of Wi-Fi communication, satellite positioning, one or more types of communications (e.g., GSM (Global System for Mobiles), CDMA

(Code Division Multiple Access), LTE (Long Term Evolution), V2X (Vehicle-to-Everything, e.g., V2P (Vehicle-to-Pedestrian), V2I (Vehicle-to-Infrastructure), V2V (Vehicle-to-Vehicle), etc.), IEEE 802.11p, etc.). V2X communications may be cellular (Cellular-V2X (C-V2X)) and/or WiFi (e.g., DSRC (Dedicated Short-Range Connection)). The system 100 may support operation on multiple carriers (waveform signals of different frequencies). Multi-carrier transmitters can transmit modulated signals simultaneously on the multiple carriers. Each modulated signal may be a Code Division Multiple Access (CDMA) signal, a Time Division Multiple Access (TDMA) signal, an Orthogonal Frequency Division Multiple Access (OFDMA) signal, a Single-Carrier Frequency Division Multiple Access (SC-FDMA) signal, etc. Each modulated signal may be sent on a different carrier and may carry pilot, overhead information, data, etc. The UEs 105, 106 may communicate with each other through UE-to-UE sidelink (SL) communications by transmitting over one or more sidelink channels such as a physical sidelink synchronization channel (PSSCH), a physical sidelink broadcast channel (PSBCH), or a physical sidelink control channel (PSCCH). Direct wireless-device-to-wireless-device communications without going through a network may be referred to generally as sidelink communications without limiting the communications to a particular protocol.

[0042] The UE 105 may comprise and/or may be referred to as a device, a mobile device, a wireless device, a mobile terminal, a terminal, a mobile station (MS), a Secure User Plane Location (SUPL) Enabled Terminal (SET), or by some other name. Moreover, the UE 105 may correspond to a cellphone, smartphone, laptop, tablet, PDA, consumer asset tracking device, navigation device, Internet of Things (IoT) device, health monitors, security systems, smart city sensors, smart meters, wearable trackers, or some other portable or moveable device. Typically, though not necessarily, the UE 105 may support wireless communication using one or more Radio Access Technologies (RATs) such as Global System for Mobile communication (GSM), Code Division Multiple Access (CDMA), Wideband CDMA (WCDMA), LTE, High Rate Packet Data (HRPD), IEEE 802.11 WiFi (also referred to as Wi-Fi), Bluetooth® (BT), Worldwide Interoperability for Microwave Access (WiMAX), 5G new radio (NR) (e.g., using the NG-RAN 135 and the 5GC 140), etc. The UE 105 may support wireless communication using a Wireless Local Area Network (WLAN) which may connect to other networks (e.g., the Internet) using a Digital Subscriber Line (DSL) or packet

cable, for example. The use of one or more of these RATs may allow the UE 105 to communicate with the external client 130 (e.g., via elements of the 5GC 140 not shown in FIG. 1, or possibly via the GMLC 125) and/or allow the external client 130 to receive location information regarding the UE 105 (e.g., via the GMLC 125).

[0043] The UE 105 may include a single entity or may include multiple entities such as in a personal area network where a user may employ audio, video and/or data I/O (input/output) devices and/or body sensors and a separate wireline or wireless modem. An estimate of a location of the UE 105 may be referred to as a location, location estimate, location fix, fix, position, position estimate, or position fix, and may be geographic, thus providing location coordinates for the UE 105 (e.g., latitude and longitude) which may or may not include an altitude component (e.g., height above sea level, height above or depth below ground level, floor level, or basement level). Alternatively, a location of the UE 105 may be expressed as a civic location (e.g., as a postal address or the designation of some point or small area in a building such as a particular room or floor). A location of the UE 105 may be expressed as an area or volume (defined either geographically or in civic form) within which the UE 105 is expected to be located with some probability or confidence level (e.g., 67%, 95%, etc.). A location of the UE 105 may be expressed as a relative location comprising, for example, a distance and direction from a known location. The relative location may be expressed as relative coordinates (e.g., X, Y (and Z) coordinates) defined relative to some origin at a known location which may be defined, e.g., geographically, in civic terms, or by reference to a point, area, or volume, e.g., indicated on a map, floor plan, or building plan. In the description contained herein, the use of the term location may comprise any of these variants unless indicated otherwise. When computing the location of a UE, it is common to solve for local x, y, and possibly z coordinates and then, if desired, convert the local coordinates into absolute coordinates (e.g., for latitude, longitude, and altitude above or below mean sea level).

[0044] The UE 105 may be configured to communicate with other entities using one or more of a variety of technologies. The UE 105 may be configured to connect indirectly to one or more communication networks via one or more device-to-device (D2D) peer-to-peer (P2P) links. The D2D P2P links may be supported with any appropriate D2D radio access technology (RAT), such as LTE Direct (LTE-D), WiFi Direct (WiFi-D), Bluetooth®, and so on. One or more of a group of UEs utilizing D2D communications

may be within a geographic coverage area of a Transmission/Reception Point (TRP) such as one or more of the gNBs 110a, 110b, and/or the ng-eNB 114. Other UEs in such a group may be outside such geographic coverage areas, or may be otherwise unable to receive transmissions from a base station. Groups of UEs communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE may transmit to other UEs in the group. A TRP may facilitate scheduling of resources for D2D communications. In other cases, D2D communications may be carried out between UEs without the involvement of a TRP. One or more of a group of UEs utilizing D2D communications may be within a geographic coverage area of a TRP. Other UEs in such a group may be outside such geographic coverage areas, or be otherwise unable to receive transmissions from a base station. Groups of UEs communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE may transmit to other UEs in the group. A TRP may facilitate scheduling of resources for D2D communications. In other cases, D2D communications may be carried out between UEs without the involvement of a TRP.

[0045] Base stations (BSs) in the NG-RAN 135 shown in FIG. 1 include NR Node Bs, referred to as the gNBs 110a and 110b. Pairs of the gNBs 110a, 110b in the NG-RAN 135 may be connected to one another via one or more other gNBs. Access to the 5G network is provided to the UE 105 via wireless communication between the UE 105 and one or more of the gNBs 110a, 110b, which may provide wireless communications access to the 5GC 140 on behalf of the UE 105 using 5G. In FIG. 1, the serving gNB for the UE 105 is assumed to be the gNB 110a, although another gNB (e.g., the gNB 110b) may act as a serving gNB if the UE 105 moves to another location or may act as a secondary gNB to provide additional throughput and bandwidth to the UE 105.

[0046] Base stations (BSs) in the NG-RAN 135 shown in FIG. 1 may include the ng-eNB 114, also referred to as a next generation evolved Node B. The ng-eNB 114 may be connected to one or more of the gNBs 110a, 110b in the NG-RAN 135, possibly via one or more other gNBs and/or one or more other ng-eNBs. The ng-eNB 114 may provide LTE wireless access and/or evolved LTE (eLTE) wireless access to the UE 105. One or more of the gNBs 110a, 110b and/or the ng-eNB 114 may be configured to function as positioning-only beacons which may transmit signals to assist with determining the position of the UE 105 but may not receive signals from the UE 105 or from other UEs.

[0047] The gNBs 110a, 110b and/or the ng-eNB 114 may each comprise one or more TRPs. For example, each sector within a cell of a BS may comprise a TRP, although multiple TRPs may share one or more components (e.g., share a processor but have separate antennas). The system 100 may include macro TRPs exclusively or the system 100 may have TRPs of different types, e.g., macro, pico, and/or femto TRPs, etc. A macro TRP may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by terminals with service subscription. A pico TRP may cover a relatively small geographic area (e.g., a pico cell) and may allow unrestricted access by terminals with service subscription. A femto or home TRP may cover a relatively small geographic area (e.g., a femto cell) and may allow restricted access by terminals having association with the femto cell (e.g., terminals for users in a home).

[0048] Each of the gNBs 110a, 110b and/or the ng-eNB 114 may include a radio unit (RU), a distributed unit (DU), and a central unit (CU). For example, the gNB 110b includes an RU 111, a DU 112, and a CU 113. The RU 111, DU 112, and CU 113 divide functionality of the gNB 110b. While the gNB 110b is shown with a single RU, a single DU, and a single CU, a gNB may include one or more RUs, one or more DUs, and/or one or more CUs. An interface between the CU 113 and the DU 112 is referred to as an F1 interface. The RU 111 is configured to perform digital front end (DFE) functions (e.g., analog-to-digital conversion, filtering, power amplification, transmission/reception) and digital beamforming, and includes a portion of the physical (PHY) layer. The RU 111 may perform the DFE using massive multiple input/multiple output (MIMO) and may be integrated with one or more antennas of the gNB 110b. The DU 112 hosts the Radio Link Control (RLC), Medium Access Control (MAC), and physical layers of the gNB 110b. One DU can support one or more cells, and each cell is supported by a single DU. The operation of the DU 112 is controlled by the CU 113. The CU 113 is configured to perform functions for transferring user data, mobility control, radio access network sharing, positioning, session management, etc. although some functions are allocated exclusively to the DU 112. The CU 113 hosts the Radio Resource Control (RRC), Service Data Adaptation Protocol (SDAP), and Packet Data Convergence Protocol (PDCP) protocols of the gNB 110b. The UE 105 may communicate with the CU 113 via RRC, SDAP, and PDCP layers, with the DU 112 via the RLC, MAC, and PHY layers, and with the RU 111 via the PHY layer.

[0049] As noted, while FIG. 1 depicts nodes configured to communicate according to 5G communication protocols, nodes configured to communicate according to other communication protocols, such as, for example, an LTE protocol or IEEE 802.11x protocol, may be used. For example, in an Evolved Packet System (EPS) providing LTE wireless access to the UE 105, a RAN may comprise an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN) which may comprise base stations comprising evolved Node Bs (eNBs). A core network for EPS may comprise an Evolved Packet Core (EPC). An EPS may comprise an E-UTRAN plus EPC, where the E-UTRAN corresponds to the NG-RAN 135 and the EPC corresponds to the 5GC 140 in FIG. 1.

[0050] The gNBs 110a, 110b and the ng-eNB 114 may communicate with the AMF 115, which, for positioning functionality, communicates with the LMF 120. The AMF 115 may support mobility of the UE 105, including cell change and handover and may participate in supporting a signaling connection to the UE 105 and possibly data and voice bearers for the UE 105. The LMF 120 may communicate directly with the UE 105, e.g., through wireless communications, or directly with the gNBs 110a, 110b and/or the ng-eNB 114. The LMF 120 may support positioning of the UE 105 when the UE 105 accesses the NG-RAN 135 and may support position procedures / methods such as Assisted GNSS (A-GNSS), Observed Time Difference of Arrival (OTDOA) (e.g., Downlink (DL) OTDOA or Uplink (UL) OTDOA), Round Trip Time (RTT), Multi-Cell RTT, Real Time Kinematic (RTK), Precise Point Positioning (PPP), Differential GNSS (DGNSS), Enhanced Cell ID (E-CID), angle of arrival (AoA), angle of departure (AoD), and/or other position methods. The LMF 120 may process location services requests for the UE 105, e.g., received from the AMF 115 or from the GMLC 125. The LMF 120 may be connected to the AMF 115 and/or to the GMLC 125. The LMF 120 may be referred to by other names such as a Location Manager (LM), Location Function (LF), commercial LMF (CLMF), or value added LMF (VLMF). A node / system that implements the LMF 120 may additionally or alternatively implement other types of location-support modules, such as an Enhanced Serving Mobile Location Center (E-SMLC) or a Secure User Plane Location (SUPL) Location Platform (SLP). At least part of the positioning functionality (including derivation of the location of the UE 105) may be performed at the UE 105 (e.g., using signal measurements obtained by the UE 105 for signals transmitted by wireless nodes such as the gNBs 110a, 110b

and/or the ng-eNB 114, and/or assistance data provided to the UE 105, e.g., by the LMF 120). The AMF 115 may serve as a control node that processes signaling between the UE 105 and the 5GC 140, and may provide QoS (Quality of Service) flow and session management. The AMF 115 may support mobility of the UE 105 including cell change and handover and may participate in supporting signaling connection to the UE 105.

[0051] The server 150, e.g., a cloud server, is configured to obtain and provide location estimates of the UE 105 to the external client 130. The server 150 may, for example, be configured to run a microservice/service that obtains the location estimate of the UE 105. The server 150 may, for example, pull the location estimate from (e.g., by sending a location request to) the UE 105, one or more of the gNBs 110a, 110b (e.g., via the RU 111, the DU 112, and the CU 113) and/or the ng-eNB 114, and/or the LMF 120. As another example, the UE 105, one or more of the gNBs 110a, 110b (e.g., via the RU 111, the DU 112, and the CU 113), and/or the LMF 120 may push the location estimate of the UE 105 to the server 150.

[0052] The GMLC 125 may support a location request for the UE 105 received from the external client 130 via the server 150 and may forward such a location request to the AMF 115 for forwarding by the AMF 115 to the LMF 120 or may forward the location request directly to the LMF 120. A location response from the LMF 120 (e.g., containing a location estimate for the UE 105) may be returned to the GMLC 125 either directly or via the AMF 115 and the GMLC 125 may then return the location response (e.g., containing the location estimate) to the external client 130 via the server 150. The GMLC 125 is shown connected to both the AMF 115 and LMF 120, though may not be connected to the AMF 115 or the LMF 120 in some implementations.

[0053] As further illustrated in FIG. 1, the LMF 120 may communicate with the gNBs 110a, 110b and/or the ng-eNB 114 using a New Radio Position Protocol A (which may be referred to as NPPa or NRPPa), which may be defined in 3GPP Technical Specification (TS) 38.455. NRPPa may be the same as, similar to, or an extension of the LTE Positioning Protocol A (LPPa) defined in 3GPP TS 36.455, with NRPPa messages being transferred between the gNB 110a (or the gNB 110b) and the LMF 120, and/or between the ng-eNB 114 and the LMF 120, via the AMF 115. As further illustrated in FIG. 1, the LMF 120 and the UE 105 may communicate using an LTE Positioning Protocol (LPP), which may be defined in 3GPP TS 36.355. The LMF 120 and the UE 105 may also or instead communicate using a New Radio Positioning

Protocol (which may be referred to as NPP or NRPP), which may be the same as, similar to, or an extension of LPP. Here, LPP and/or NPP messages may be transferred between the UE 105 and the LMF 120 via the AMF 115 and the serving gNB 110a, 110b or the serving ng-eNB 114 for the UE 105. For example, LPP and/or NPP messages may be transferred between the LMF 120 and the AMF 115 using a 5G Location Services Application Protocol (LCS AP) and may be transferred between the AMF 115 and the UE 105 using a 5G Non-Access Stratum (NAS) protocol. The LPP and/or NPP protocol may be used to support positioning of the UE 105 using UE-assisted and/or UE-based position methods such as A-GNSS, RTK, OTDOA and/or E-CID. The NRPPa protocol may be used to support positioning of the UE 105 using network-based position methods such as E-CID (e.g., when used with measurements obtained by the gNB 110a, 110b or the ng-eNB 114) and/or may be used by the LMF 120 to obtain location related information from the gNBs 110a, 110b and/or the ng-eNB 114, such as parameters defining directional SS or PRS transmissions from the gNBs 110a, 110b, and/or the ng-eNB 114. The LMF 120 may be co-located or integrated with a gNB or a TRP, or may be disposed remote from the gNB and/or the TRP and configured to communicate directly or indirectly with the gNB and/or the TRP.

[0054] With a UE-assisted position method, the UE 105 may obtain location measurements and send the measurements to a location server (e.g., the LMF 120) for computation of a location estimate for the UE 105. For example, the location measurements may include one or more of a Received Signal Strength Indication (RSSI), Round Trip signal propagation Time (RTT), Reference Signal Time Difference (RSTD), Reference Signal Received Power (RSRP) and/or Reference Signal Received Quality (RSRQ) for the gNBs 110a, 110b, the ng-eNB 114, and/or a WLAN AP. The location measurements may also or instead include measurements of GNSS pseudorange, code phase, and/or carrier phase for the SVs 190-193.

[0055] With a UE-based position method, the UE 105 may obtain location measurements (e.g., which may be the same as or similar to location measurements for a UE-assisted position method) and may compute a location of the UE 105 (e.g., with the help of assistance data received from a location server such as the LMF 120 or broadcast by the gNBs 110a, 110b, the ng-eNB 114, or other base stations or APs).

[0056] With a network-based position method, one or more base stations (e.g., the gNBs 110a, 110b, and/or the ng-eNB 114) or APs may obtain location measurements

(e.g., measurements of RSSI, RTT, RSRP, RSRQ or Time of Arrival (ToA) for signals transmitted by the UE 105) and/or may receive measurements obtained by the UE 105. The one or more base stations or APs may send the measurements to a location server (e.g., the LMF 120) for computation of a location estimate for the UE 105.

[0057] Information provided by the gNBs 110a, 110b, and/or the ng-eNB 114 to the LMF 120 using NRPPa may include timing and configuration information for directional SS or PRS transmissions and location coordinates. The LMF 120 may provide some or all of this information to the UE 105 as assistance data in an LPP and/or NPP message via the NG-RAN 135 and the 5GC 140.

[0058] An LPP or NPP message sent from the LMF 120 to the UE 105 may instruct the UE 105 to do any of a variety of things depending on desired functionality. For example, the LPP or NPP message could contain an instruction for the UE 105 to obtain measurements for GNSS (or A-GNSS), WLAN, E-CID, and/or OTDOA (or some other position method). In the case of E-CID, the LPP or NPP message may instruct the UE 105 to obtain one or more measurement quantities (e.g., beam ID, beam width, mean angle, RSRP, RSRQ measurements) of directional signals transmitted within particular cells supported by one or more of the gNBs 110a, 110b, and/or the ng-eNB 114 (or supported by some other type of base station such as an eNB or WiFi AP). The UE 105 may send the measurement quantities back to the LMF 120 in an LPP or NPP message (e.g., inside a 5G NAS message) via the serving gNB 110a (or the serving ng-eNB 114) and the AMF 115.

[0059] As noted, while the communication system 100 is described in relation to 5G technology, the communication system 100 may be implemented to support other communication technologies, such as GSM, WCDMA, LTE, etc., that are used for supporting and interacting with mobile devices such as the UE 105 (e.g., to implement voice, data, positioning, and other functionalities). In some such embodiments, the 5GC 140 may be configured to control different air interfaces. For example, the 5GC 140 may be connected to a WLAN using a Non-3GPP InterWorking Function (N3IWF, not shown FIG. 1) in the 5GC 140. For example, the WLAN may support IEEE 802.11 WiFi access for the UE 105 and may comprise one or more WiFi APs. Here, the N3IWF may connect to the WLAN and to other elements in the 5GC 140 such as the AMF 115. In some embodiments, both the NG-RAN 135 and the 5GC 140 may be replaced by one or more other RANs and one or more other core networks. For

example, in an EPS, the NG-RAN 135 may be replaced by an E-UTRAN containing eNBs and the 5GC 140 may be replaced by an EPC containing a Mobility Management Entity (MME) in place of the AMF 115, an E-SMLC in place of the LMF 120, and a GMLC that may be similar to the GMLC 125. In such an EPS, the E-SMLC may use LPPa in place of NRPPa to send and receive location information to and from the eNBs in the E-UTRAN and may use LPP to support positioning of the UE 105. In these other embodiments, positioning of the UE 105 using directional PRSs may be supported in an analogous manner to that described herein for a 5G network with the difference that functions and procedures described herein for the gNBs 110a, 110b, the ng-eNB 114, the AMF 115, and the LMF 120 may, in some cases, apply instead to other network elements such eNBs, WiFi APs, an MME, and an E-SMLC.

[0060] As noted, in some embodiments, positioning functionality may be implemented, at least in part, using the directional SS or PRS beams, sent by base stations (such as the gNBs 110a, 110b, and/or the ng-eNB 114) that are within range of the UE whose position is to be determined (e.g., the UE 105 of FIG. 1). The UE may, in some instances, use the directional SS or PRS beams from a plurality of base stations (such as the gNBs 110a, 110b, the ng-eNB 114, etc.) to compute the UE's position.

[0061] Referring also to FIG. 2, a UE 200 may be an example of one of the UEs 105, 106 and may comprise a computing platform including a processor 210, memory 211 including software (SW) 212, one or more sensors 213, a transceiver interface 214 for a transceiver 215 (that includes a wireless transceiver 240 and a wired transceiver 250), a user interface 216, a Satellite Positioning System (SPS) receiver 217, a camera 218, and a position device (PD) 219. The processor 210, the memory 211, the sensor(s) 213, the transceiver interface 214, the user interface 216, the SPS receiver 217, the camera 218, and the position device 219 may be communicatively coupled to each other by a bus 220 (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., the camera 218, the position device 219, and/or one or more of the sensor(s) 213, etc.) may be omitted from the UE 200. The processor 210 may include one or more intelligent hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor 210 may comprise multiple processors including a general-purpose/application processor 230, a Digital Signal Processor (DSP) 231, a modem processor 232, a video processor 233, and/or a sensor processor 234. One or more of

the processors 230-234 may comprise multiple devices (e.g., multiple processors). For example, the sensor processor 234 may comprise, e.g., processors for RF (radio frequency) sensing (with one or more (cellular) wireless signals transmitted and reflection(s) used to identify, map, and/or track an object), and/or ultrasound, etc. The modem processor 232 may support dual SIM/dual connectivity (or even more SIMs). For example, a SIM (Subscriber Identity Module or Subscriber Identification Module) may be used by an Original Equipment Manufacturer (OEM), and another SIM may be used by an end user of the UE 200 for connectivity. The memory 211 may be a non-transitory storage medium that may include random access memory (RAM), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory 211 may store the software 212 which may be processor-readable, processor-executable software code containing instructions that may be configured to, when executed, cause the processor 210 to perform various functions described herein. Alternatively, the software 212 may not be directly executable by the processor 210 but may be configured to cause the processor 210, e.g., when compiled and executed, to perform the functions. The description herein may refer to the processor 210 performing a function, but this includes other implementations such as where the processor 210 executes software and/or firmware. The description herein may refer to the processor 210 performing a function as shorthand for one or more of the processors 230-234 performing the function. The description herein may refer to the UE 200 performing a function as shorthand for one or more appropriate components of the UE 200 performing the function. The processor 210 may include a memory with stored instructions in addition to and/or instead of the memory 211. Functionality of the processor 210 is discussed more fully below.

[0062] The configuration of the UE 200 shown in FIG. 2 is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, an example configuration of the UE may include one or more of the processors 230-234 of the processor 210, the memory 211, and the wireless transceiver 240. Other example configurations may include one or more of the processors 230-234 of the processor 210, the memory 211, a wireless transceiver, and one or more of the sensor(s) 213, the user interface 216, the SPS receiver 217, the camera 218, the PD 219, and/or a wired transceiver.

[0063] The UE 200 may comprise the modem processor 232 that may be capable of performing baseband processing of signals received and down-converted by the transceiver 215 and/or the SPS receiver 217. The modem processor 232 may perform baseband processing of signals to be upconverted for transmission by the transceiver 215. Also or alternatively, baseband processing may be performed by the general-purpose/application processor 230 and/or the DSP 231. Other configurations, however, may be used to perform baseband processing.

[0064] The UE 200 may include the sensor(s) 213 that may include, for example, one or more of various types of sensors such as one or more inertial sensors, one or more magnetometers, one or more environment sensors, one or more optical sensors, one or more weight sensors, and/or one or more radio frequency (RF) sensors, etc. An inertial measurement unit (IMU) may comprise, for example, one or more accelerometers (e.g., collectively responding to acceleration of the UE 200 in three dimensions) and/or one or more gyroscopes (e.g., three-dimensional gyroscope(s)). The sensor(s) 213 may include one or more magnetometers (e.g., three-dimensional magnetometer(s)) to determine orientation (e.g., relative to magnetic north and/or true north) that may be used for any of a variety of purposes, e.g., to support one or more compass applications. The environment sensor(s) may comprise, for example, one or more temperature sensors, one or more barometric pressure sensors, one or more ambient light sensors, one or more camera imagers, and/or one or more microphones, etc. The sensor(s) 213 may generate analog and/or digital signals indications of which may be stored in the memory 211 and processed by the DSP 231 and/or the general-purpose/application processor 230 in support of one or more applications such as, for example, applications directed to positioning and/or navigation operations.

[0065] The sensor(s) 213 may be used in relative location measurements, relative location determination, motion determination, etc. Information detected by the sensor(s) 213 may be used for motion detection, relative displacement, dead reckoning, sensor-based location determination, and/or sensor-assisted location determination. The sensor(s) 213 may be useful to determine whether the UE 200 is fixed (stationary) or mobile and/or whether to report certain useful information to the LMF 120 regarding the mobility of the UE 200. For example, based on the information obtained/measured by the sensor(s) 213, the UE 200 may notify/report to the LMF 120 that the UE 200 has detected movements or that the UE 200 has moved, and may report the relative

displacement/distance (e.g., via dead reckoning, or sensor-based location determination, or sensor-assisted location determination enabled by the sensor(s) 213). In another example, for relative positioning information, the sensors/IMU may be used to determine the angle and/or orientation of the other device with respect to the UE 200, etc.

[0066] The IMU may be configured to provide measurements about a direction of motion and/or a speed of motion of the UE 200, which may be used in relative location determination. For example, one or more accelerometers and/or one or more gyroscopes of the IMU may detect, respectively, a linear acceleration and a speed of rotation of the UE 200. The linear acceleration and speed of rotation measurements of the UE 200 may be integrated over time to determine an instantaneous direction of motion as well as a displacement of the UE 200. The instantaneous direction of motion and the displacement may be integrated to track a location of the UE 200. For example, a reference location of the UE 200 may be determined, e.g., using the SPS receiver 217 (and/or by some other means) for a moment in time and measurements from the accelerometer(s) and gyroscope(s) taken after this moment in time may be used in dead reckoning to determine present location of the UE 200 based on movement (direction and distance) of the UE 200 relative to the reference location.

[0067] The magnetometer(s) may determine magnetic field strengths in different directions which may be used to determine orientation of the UE 200. For example, the orientation may be used to provide a digital compass for the UE 200. The magnetometer(s) may include a two-dimensional magnetometer configured to detect and provide indications of magnetic field strength in two orthogonal dimensions. The magnetometer(s) may include a three-dimensional magnetometer configured to detect and provide indications of magnetic field strength in three orthogonal dimensions. The magnetometer(s) may provide means for sensing a magnetic field and providing indications of the magnetic field, e.g., to the processor 210.

[0068] The transceiver 215 may include a wireless transceiver 240 and a wired transceiver 250 configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver 240 may include a wireless transmitter 242 and a wireless receiver 244 coupled to an antenna 246 for transmitting (e.g., on one or more uplink channels and/or one or more sidelink channels) and/or receiving (e.g., on one or more downlink channels and/or one

or more sidelink channels) wireless signals 248 and transducing signals from the wireless signals 248 to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals 248. The wireless transmitter 242 includes appropriate components (e.g., a power amplifier and a digital-to-analog converter). The wireless receiver 244 includes appropriate components (e.g., one or more amplifiers, one or more frequency filters, and an analog-to-digital converter). The wireless transmitter 242 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver 244 may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver 240 may be configured to communicate signals (e.g., with TRPs and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi, WiFi Direct (WiFi-D), Bluetooth®, Zigbee etc. New Radio may use mm-wave frequencies and/or sub-6GHz frequencies. The wired transceiver 250 may include a wired transmitter 252 and a wired receiver 254 configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN 135 to send communications to, and receive communications from, the NG-RAN 135. The wired transmitter 252 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver 254 may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver 250 may be configured, e.g., for optical communication and/or electrical communication. The transceiver 215 may be communicatively coupled to the transceiver interface 214, e.g., by optical and/or electrical connection. The transceiver interface 214 may be at least partially integrated with the transceiver 215. The wireless transmitter 242, the wireless receiver 244, and/or the antenna 246 may include multiple transmitters, multiple receivers, and/or multiple antennas, respectively, for sending and/or receiving, respectively, appropriate signals.

[0069] The user interface 216 may comprise one or more of several devices such as, for example, a speaker, microphone, display device, vibration device, keyboard, touch

screen, etc. The user interface 216 may include more than one of any of these devices. The user interface 216 may be configured to enable a user to interact with one or more applications hosted by the UE 200. For example, the user interface 216 may store indications of analog and/or digital signals in the memory 211 to be processed by DSP 231 and/or the general-purpose/application processor 230 in response to action from a user. Similarly, applications hosted on the UE 200 may store indications of analog and/or digital signals in the memory 211 to present an output signal to a user. The user interface 216 may include an audio input/output (I/O) device comprising, for example, a speaker, a microphone, digital-to-analog circuitry, analog-to-digital circuitry, an amplifier and/or gain control circuitry (including more than one of any of these devices). Other configurations of an audio I/O device may be used. Also or alternatively, the user interface 216 may comprise one or more touch sensors responsive to touching and/or pressure, e.g., on a keyboard and/or touch screen of the user interface 216.

[0070] The SPS receiver 217 (e.g., a Global Positioning System (GPS) receiver) may be capable of receiving and acquiring SPS signals 260 via an SPS antenna 262. The SPS antenna 262 is configured to transduce the SPS signals 260 from wireless signals to wired signals, e.g., electrical or optical signals, and may be integrated with the antenna 246. The SPS receiver 217 may be configured to process, in whole or in part, the acquired SPS signals 260 for estimating a location of the UE 200. For example, the SPS receiver 217 may be configured to determine location of the UE 200 by trilateration using the SPS signals 260. The general-purpose/application processor 230, the memory 211, the DSP 231 and/or one or more specialized processors (not shown) may be utilized to process acquired SPS signals, in whole or in part, and/or to calculate an estimated location of the UE 200, in conjunction with the SPS receiver 217. The memory 211 may store indications (e.g., measurements) of the SPS signals 260 and/or other signals (e.g., signals acquired from the wireless transceiver 240) for use in performing positioning operations. The general-purpose/application processor 230, the DSP 231, and/or one or more specialized processors, and/or the memory 211 may provide or support a location engine for use in processing measurements to estimate a location of the UE 200.

[0071] The UE 200 may include the camera 218 for capturing still or moving imagery. The camera 218 may comprise, for example, an imaging sensor (e.g., a charge coupled

device or a CMOS (Complementary Metal-Oxide Semiconductor) imager), a lens, analog-to-digital circuitry, frame buffers, etc. Additional processing, conditioning, encoding, and/or compression of signals representing captured images may be performed by the general-purpose/application processor 230 and/or the DSP 231. Also or alternatively, the video processor 233 may perform conditioning, encoding, compression, and/or manipulation of signals representing captured images. The video processor 233 may decode/decompress stored image data for presentation on a display device (not shown), e.g., of the user interface 216.

[0072] The position device (PD) 219 may be configured to determine a position of the UE 200, motion of the UE 200, and/or relative position of the UE 200, and/or time. For example, the PD 219 may communicate with, and/or include some or all of, the SPS receiver 217. The PD 219 may work in conjunction with the processor 210 and the memory 211 as appropriate to perform at least a portion of one or more positioning methods, although the description herein may refer to the PD 219 being configured to perform, or performing, in accordance with the positioning method(s). The PD 219 may also or alternatively be configured to determine location of the UE 200 using terrestrial-based signals (e.g., at least some of the wireless signals 248) for trilateration, for assistance with obtaining and using the SPS signals 260, or both. The PD 219 may be configured to determine location of the UE 200 based on a cell of a serving base station (e.g., a cell center) and/or another technique such as E-CID. The PD 219 may be configured to use one or more images from the camera 218 and image recognition combined with known locations of landmarks (e.g., natural landmarks such as mountains and/or artificial landmarks such as buildings, bridges, streets, etc.) to determine location of the UE 200. The PD 219 may be configured to use one or more other techniques (e.g., relying on the UE's self-reported location (e.g., part of the UE's position beacon)) for determining the location of the UE 200, and may use a combination of techniques (e.g., SPS and terrestrial positioning signals) to determine the location of the UE 200. The PD 219 may include one or more of the sensors 213 (e.g., gyroscope(s), accelerometer(s), magnetometer(s), etc.) that may sense orientation and/or motion of the UE 200 and provide indications thereof that the processor 210 (e.g., the general-purpose/application processor 230 and/or the DSP 231) may be configured to use to determine motion (e.g., a velocity vector and/or an acceleration vector) of the UE 200. The PD 219 may be configured to provide indications of uncertainty and/or error

in the determined position and/or motion. Functionality of the PD 219 may be provided in a variety of manners and/or configurations, e.g., by the general-purpose/application processor 230, the transceiver 215, the SPS receiver 217, and/or another component of the UE 200, and may be provided by hardware, software, firmware, or various combinations thereof.

[0073] Referring also to FIG. 3, an example of a TRP 300 of the gNBs 110a, 110b and/or the ng-eNB 114 comprises a computing platform including a processor 310, memory 311 including software (SW) 312, and a transceiver 315. The processor 310, the memory 311, and the transceiver 315 may be communicatively coupled to each other by a bus 320 (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., a wireless transceiver) may be omitted from the TRP 300. The processor 310 may include one or more intelligent hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor 310 may comprise multiple processors (e.g., including a general-purpose/application processor, a DSP, a modem processor, a video processor, and/or a sensor processor as shown in FIG. 2). The memory 311 may be a non-transitory storage medium that may include random access memory (RAM)), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory 311 may store the software 312 which may be processor-readable, processor-executable software code containing instructions that are configured to, when executed, cause the processor 310 to perform various functions described herein. Alternatively, the software 312 may not be directly executable by the processor 310 but may be configured to cause the processor 310, e.g., when compiled and executed, to perform the functions.

[0074] The description herein may refer to the processor 310 performing a function, but this includes other implementations such as where the processor 310 executes software and/or firmware. The description herein may refer to the processor 310 performing a function as shorthand for one or more of the processors contained in the processor 310 performing the function. The description herein may refer to the TRP 300 performing a function as shorthand for one or more appropriate components (e.g., the processor 310 and the memory 311) of the TRP 300 (and thus of one of the gNBs 110a, 110b and/or the ng-eNB 114) performing the function. The processor 310 may include a memory

with stored instructions in addition to and/or instead of the memory 311. Functionality of the processor 310 is discussed more fully below.

[0075] The transceiver 315 may include a wireless transceiver 340 and/or a wired transceiver 350 configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver 340 may include a wireless transmitter 342 and a wireless receiver 344 coupled to one or more antennas 346 for transmitting (e.g., on one or more uplink channels and/or one or more downlink channels) and/or receiving (e.g., on one or more downlink channels and/or one or more uplink channels) wireless signals 348 and transducing signals from the wireless signals 348 to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals 348. Thus, the wireless transmitter 342 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver 344 may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver 340 may be configured to communicate signals (e.g., with the UE 200, one or more other UEs, and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi, WiFi Direct (WiFi-D), Bluetooth®, Zigbee etc. The wired transceiver 350 may include a wired transmitter 352 and a wired receiver 354 configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN 135 to send communications to, and receive communications from, the LMF 120, for example, and/or one or more other network entities. The wired transmitter 352 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver 354 may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver 350 may be configured, e.g., for optical communication and/or electrical communication.

[0076] The configuration of the TRP 300 shown in FIG. 3 is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, the description herein discusses that the TRP 300 may be configured to

perform or performs several functions, but one or more of these functions may be performed by the LMF 120 and/or the UE 200 (i.e., the LMF 120 and/or the UE 200 may be configured to perform one or more of these functions).

[0077] Referring also to FIG. 4, a server 400, of which the LMF 120 may be an example, may comprise a computing platform including a processor 410, memory 411 including software (SW) 412, and a transceiver 415. The processor 410, the memory 411, and the transceiver 415 may be communicatively coupled to each other by a bus 420 (which may be configured, e.g., for optical and/or electrical communication). One or more of the shown apparatus (e.g., a wireless transceiver) may be omitted from the server 400. The processor 410 may include one or more intelligent hardware devices, e.g., a central processing unit (CPU), a microcontroller, an application specific integrated circuit (ASIC), etc. The processor 410 may comprise multiple processors (e.g., including a general-purpose/application processor, a DSP, a modem processor, a video processor, and/or a sensor processor as shown in FIG. 2). The memory 411 may be a non-transitory storage medium that may include random access memory (RAM)), flash memory, disc memory, and/or read-only memory (ROM), etc. The memory 411 may store the software 412 which may be processor-readable, processor-executable software code containing instructions that are configured to, when executed, cause the processor 410 to perform various functions described herein. Alternatively, the software 412 may not be directly executable by the processor 410 but may be configured to cause the processor 410, e.g., when compiled and executed, to perform the functions. The description herein may refer to the processor 410 performing a function, but this includes other implementations such as where the processor 410 executes software and/or firmware. The description herein may refer to the processor 410 performing a function as shorthand for one or more of the processors contained in the processor 410 performing the function. The description herein may refer to the server 400 performing a function as shorthand for one or more appropriate components of the server 400 performing the function. The processor 410 may include a memory with stored instructions in addition to and/or instead of the memory 411. Functionality of the processor 410 is discussed more fully below.

[0078] The transceiver 415 may include a wireless transceiver 440 and/or a wired transceiver 450 configured to communicate with other devices through wireless connections and wired connections, respectively. For example, the wireless transceiver

440 may include a wireless transmitter 442 and a wireless receiver 444 coupled to one or more antennas 446 for transmitting (e.g., on one or more downlink channels) and/or receiving (e.g., on one or more uplink channels) wireless signals 448 and transducing signals from the wireless signals 448 to wired (e.g., electrical and/or optical) signals and from wired (e.g., electrical and/or optical) signals to the wireless signals 448. Thus, the wireless transmitter 442 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wireless receiver 444 may include multiple receivers that may be discrete components or combined/integrated components. The wireless transceiver 440 may be configured to communicate signals (e.g., with the UE 200, one or more other UEs, and/or one or more other devices) according to a variety of radio access technologies (RATs) such as 5G New Radio (NR), GSM (Global System for Mobiles), UMTS (Universal Mobile Telecommunications System), AMPS (Advanced Mobile Phone System), CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), LTE (Long Term Evolution), LTE Direct (LTE-D), 3GPP LTE-V2X (PC5), IEEE 802.11 (including IEEE 802.11p), WiFi, WiFi Direct (WiFi-D), Bluetooth®, Zigbee etc. The wired transceiver 450 may include a wired transmitter 452 and a wired receiver 454 configured for wired communication, e.g., a network interface that may be utilized to communicate with the NG-RAN 135 to send communications to, and receive communications from, the TRP 300, for example, and/or one or more other network entities. The wired transmitter 452 may include multiple transmitters that may be discrete components or combined/integrated components, and/or the wired receiver 454 may include multiple receivers that may be discrete components or combined/integrated components. The wired transceiver 450 may be configured, e.g., for optical communication and/or electrical communication.

[0079] The description herein may refer to the processor 410 performing a function, but this includes other implementations such as where the processor 410 executes software (stored in the memory 411) and/or firmware. The description herein may refer to the server 400 performing a function as shorthand for one or more appropriate components (e.g., the processor 410 and the memory 411) of the server 400 performing the function.

[0080] The configuration of the server 400 shown in FIG. 4 is an example and not limiting of the disclosure, including the claims, and other configurations may be used. For example, the wireless transceiver 440 may be omitted. Also or alternatively, the

description herein discusses that the server 400 is configured to perform or performs several functions, but one or more of these functions may be performed by the TRP 300 and/or the UE 200 (i.e., the TRP 300 and/or the UE 200 may be configured to perform one or more of these functions).

[0081] **Positioning Techniques**

[0082] For terrestrial positioning of a UE in cellular networks, techniques such as Advanced Forward Link Trilateration (AFLT) and Observed Time Difference Of Arrival (OTDOA) often operate in "UE-assisted" mode in which measurements of reference signals (e.g., PRS, CRS, etc.) transmitted by base stations are taken by the UE and then provided to a location server. The location server then calculates the position of the UE based on the measurements and known locations of the base stations. Because these techniques use the location server to calculate the position of the UE, rather than the UE itself, these positioning techniques are not frequently used in applications such as car or cell-phone navigation, which instead typically rely on satellite-based positioning.

[0083] A UE may use a Satellite Positioning System (SPS) (a Global Navigation Satellite System (GNSS)) for high-accuracy positioning using precise point positioning (PPP) or real time kinematic (RTK) technology. These technologies use assistance data such as measurements from ground-based stations. LTE Release 15 allows the data to be encrypted so that the UEs subscribed to the service exclusively can read the information. Such assistance data varies with time. Thus, a UE subscribed to the service may not easily "break encryption" for other UEs by passing on the data to other UEs that have not paid for the subscription. The passing on would need to be repeated every time the assistance data changes.

[0084] In UE-assisted positioning, the UE sends measurements (e.g., TDOA, Angle of Arrival (AoA), etc.) to the positioning server (e.g., LMF/eSMLC). The positioning server has the base station almanac (BSA) that contains multiple 'entries' or 'records', one record per cell, where each record contains geographical cell location but also may include other data. An identifier of the 'record' among the multiple 'records' in the BSA may be referenced. The BSA and the measurements from the UE may be used to compute the position of the UE.

[0085] In conventional UE-based positioning, a UE computes its own position, thus avoiding sending measurements to the network (e.g., location server), which in turn

improves latency and scalability. The UE uses relevant BSA record information (e.g., locations of gNBs (more broadly base stations)) from the network. The BSA information may be encrypted. But since the BSA information varies much less often than, for example, the PPP or RTK assistance data described earlier, it may be easier to make the BSA information (compared to the PPP or RTK information) available to UEs that did not subscribe and pay for decryption keys. Transmissions of reference signals by the gNBs make BSA information potentially accessible to crowd-sourcing or war-driving, essentially enabling BSA information to be generated based on in-the-field and/or over-the-top observations.

[0086] Positioning techniques may be characterized and/or assessed based on one or more criteria such as position determination accuracy and/or latency. Latency is a time elapsed between an event that triggers determination of position-related data and the availability of that data at a positioning system interface, e.g., an interface of the LMF 120. At initialization of a positioning system, the latency for the availability of position-related data is called time to first fix (TTFF), and is larger than latencies after the TTFF. An inverse of a time elapsed between two consecutive position-related data availabilities is called an update rate, i.e., the rate at which position-related data are generated after the first fix. Latency may depend on processing capability, e.g., of the UE. For example, a UE may report a processing capability of the UE as a duration of DL PRS symbols in units of time (e.g., milliseconds) that the UE can process every T amount of time (e.g., T ms) assuming 272 PRB (Physical Resource Block) allocation. Other examples of capabilities that may affect latency are a number of TRPs from which the UE can process PRS, a number of PRS that the UE can process, and a bandwidth of the UE.

[0087] One or more of many different positioning techniques (also called positioning methods) may be used to determine position of an entity such as one of the UEs 105, 106. For example, known position-determination techniques include RTT, multi-RTT, OTDOA (also called TDOA and including UL-TDOA and DL-TDOA), Enhanced Cell Identification (E-CID), DL-AoD, UL-AoA, etc. RTT uses a time for a signal to travel from one entity to another and back to determine a range between the two entities. The range, plus a known location of a first one of the entities and an angle between the two entities (e.g., an azimuth angle) can be used to determine a location of the second of the entities. In multi-RTT (also called multi-cell RTT), multiple ranges from one entity

(e.g., a UE) to other entities (e.g., TRPs) and known locations of the other entities may be used to determine the location of the one entity. In TDOA techniques, the difference in travel times between one entity and other entities may be used to determine relative ranges from the other entities and those, combined with known locations of the other entities may be used to determine the location of the one entity. Angles of arrival and/or departure may be used to help determine location of an entity. For example, an angle of arrival or an angle of departure of a signal combined with a range between devices (determined using signal, e.g., a travel time of the signal, a received power of the signal, etc.) and a known location of one of the devices may be used to determine a location of the other device. The angle of arrival or departure may be an azimuth angle relative to a reference direction such as true north. The angle of arrival or departure may be a zenith angle relative to directly upward from an entity (i.e., relative to radially outward from a center of Earth). E-CID uses the identity of a serving cell, the timing advance (i.e., the difference between receive and transmit times at the UE), estimated timing and power of detected neighbor cell signals, and possibly angle of arrival (e.g., of a signal at the UE from the base station or vice versa) to determine location of the UE. In TDOA, the difference in arrival times at a receiving device of signals from different sources along with known locations of the sources and known offset of transmission times from the sources are used to determine the location of the receiving device.

[0088] In a network-centric RTT estimation, the serving base station instructs the UE to scan for / receive RTT measurement signals (e.g., PRS) on serving cells of two or more neighboring base stations (and typically the serving base station, as at least three base stations are needed). The one of more base stations transmit RTT measurement signals on low reuse resources (e.g., resources used by the base station to transmit system information) allocated by the network (e.g., a location server such as the LMF 120). The UE records the arrival time (also referred to as a receive time, a reception time, a time of reception, or a time of arrival (ToA)) of each RTT measurement signal relative to the UE's current downlink timing (e.g., as derived by the UE from a DL signal received from its serving base station), and transmits a common or individual RTT response message (e.g., SRS (sounding reference signal) for positioning, i.e., UL-PRS) to the one or more base stations (e.g., when instructed by its serving base station) and may include the time difference $T_{Rx \rightarrow Tx}$ (i.e., UE $T_{Rx\text{-}Tx}$ or $UE_{Rx\text{-}Tx}$) between the ToA of

the RTT measurement signal and the transmission time of the RTT response message in a payload of each RTT response message. The RTT response message would include a reference signal from which the base station can deduce the ToA of the RTT response. By comparing the difference $T_{Tx \rightarrow Rx}$ between the transmission time of the RTT measurement signal from the base station and the ToA of the RTT response at the base station to the UE-reported time difference $T_{Rx \rightarrow Tx}$, and subtracting the UE_{Rx-Tx}, the base station can deduce the propagation time between the base station and the UE, from which the base station can determine the distance between the UE and the base station by assuming the speed of light during this propagation time.

[0089] A UE-centric RTT estimation is similar to the network-based method, except that the UE transmits uplink RTT measurement signal(s) (e.g., when instructed by a serving base station), which are received by multiple base stations in the neighborhood of the UE. Each involved base station responds with a downlink RTT response message, which may include the time difference between the ToA of the RTT measurement signal at the base station and the transmission time of the RTT response message from the base station in the RTT response message payload.

[0090] For both network-centric and UE-centric procedures, the side (network or UE) that performs the RTT calculation typically (though not always) transmits the first message(s) or signal(s) (e.g., RTT measurement signal(s)), while the other side responds with one or more RTT response message(s) or signal(s) that may include the difference between the ToA of the first message(s) or signal(s) and the transmission time of the RTT response message(s) or signal(s).

[0091] A multi-RTT technique may be used to determine position. For example, a first entity (e.g., a UE) may send out one or more signals (e.g., unicast, multicast, or broadcast from the base station) and multiple second entities (e.g., other TSPs such as base station(s) and/or UE(s)) may receive a signal from the first entity and respond to this received signal. The first entity receives the responses from the multiple second entities. The first entity (or another entity such as an LMF) may use the responses from the second entities to determine ranges to the second entities and may use the multiple ranges and known locations of the second entities to determine the location of the first entity by trilateration.

[0092] In some instances, additional information may be obtained in the form of an angle of arrival (AoA) or angle of departure (AoD) that defines a straight-line direction

(e.g., which may be in a horizontal plane or in three dimensions) or possibly a range of directions (e.g., for the UE from the locations of base stations). The intersection of two directions can provide another estimate of the location for the UE.

[0093] For positioning techniques using PRS (Positioning Reference Signal) signals (e.g., TDOA and RTT), PRS signals sent by multiple TRPs are measured and the arrival times of the signals, known transmission times, and known locations of the TRPs used to determine ranges from a UE to the TRPs. For example, an RSTD (Reference Signal Time Difference) may be determined for PRS signals received from multiple TRPs and used in a TDOA technique to determine position (location) of the UE. A positioning reference signal may be referred to as a PRS or a PRS signal. The PRS signals are typically sent using the same power and PRS signals with the same signal characteristics (e.g., same frequency shift) may interfere with each other such that a PRS signal from a more distant TRP may be overwhelmed by a PRS signal from a closer TRP such that the signal from the more distant TRP may not be detected. PRS muting may be used to help reduce interference by muting some PRS signals (reducing the power of the PRS signal, e.g., to zero and thus not transmitting the PRS signal). In this way, a weaker (at the UE) PRS signal may be more easily detected by the UE without a stronger PRS signal interfering with the weaker PRS signal. The term RS, and variations thereof (e.g., PRS, SRS, CSI-RS (Channel State Information – Reference Signal)), may refer to one reference signal or more than one reference signal.

[0094] Positioning reference signals (PRS) include downlink PRS (DL PRS, often referred to simply as PRS) and uplink PRS (UL PRS) (which may be called SRS (Sounding Reference Signal) for positioning). A PRS may comprise a PN code (pseudorandom number code) or be generated using a PN code (e.g., by modulating a carrier signal with the PN code) such that a source of the PRS may serve as a pseudo-satellite (a pseudolite). The PN code may be unique to the PRS source (at least within a specified area such that identical PRS from different PRS sources do not overlap). PRS may comprise PRS resources and/or PRS resource sets of a frequency layer. A DL PRS positioning frequency layer (or simply a frequency layer) is a collection of DL PRS resource sets, from one or more TRPs, with PRS resource(s) that have common parameters configured by higher-layer parameters *DL-PRS-PositioningFrequencyLayer*, *DL-PRS-ResourceSet*, and *DL-PRS-Resource*. Each frequency layer has a DL PRS subcarrier spacing (SCS) for the DL PRS resource sets and the DL PRS resources in the

frequency layer. Each frequency layer has a DL PRS cyclic prefix (CP) for the DL PRS resource sets and the DL PRS resources in the frequency layer. In 5G, a resource block occupies 12 consecutive subcarriers and a specified number of symbols. Common resource blocks are the set of resource blocks that occupy a channel bandwidth. A bandwidth part (BWP) is a set of contiguous common resource blocks and may include all the common resource blocks within a channel bandwidth or a subset of the common resource blocks. Also, a DL PRS Point A parameter defines a frequency of a reference resource block (and the lowest subcarrier of the resource block), with DL PRS resources belonging to the same DL PRS resource set having the same Point A and all DL PRS resource sets belonging to the same frequency layer having the same Point A. A frequency layer also has the same DL PRS bandwidth, the same start PRB (and center frequency), and the same value of comb size (i.e., a frequency of PRS resource elements per symbol such that for comb-N, every N^{th} resource element is a PRS resource element). A PRS resource set is identified by a PRS resource set ID and may be associated with a particular TRP (identified by a cell ID) transmitted by an antenna panel of a base station. A PRS resource ID in a PRS resource set may be associated with an omnidirectional signal, and/or with a single beam (and/or beam ID) transmitted from a single base station (where a base station may transmit one or more beams). Each PRS resource of a PRS resource set may be transmitted on a different beam and as such, a PRS resource (or simply resource) can also be referred to as a beam. This does not have any implications on whether the base stations and the beams on which PRS are transmitted are known to the UE.

[0095] A TRP may be configured, e.g., by instructions received from a server and/or by software in the TRP, to send DL PRS per a schedule. According to the schedule, the TRP may send the DL PRS intermittently, e.g., periodically at a consistent interval from an initial transmission. The TRP may be configured to send one or more PRS resource sets. A resource set is a collection of PRS resources across one TRP, with the resources having the same periodicity, a common muting pattern configuration (if any), and the same repetition factor across slots. Each of the PRS resource sets comprises multiple PRS resources, with each PRS resource comprising multiple OFDM (Orthogonal Frequency Division Multiplexing) Resource Elements (REs) that may be in multiple Resource Blocks (RBs) within N (one or more) consecutive symbol(s) within a slot. PRS resources (or reference signal (RS) resources generally) may be referred to as

OFDM PRS resources (or OFDM RS resources). An RB is a collection of REs spanning a quantity of one or more consecutive symbols in the time domain and a quantity (12 for a 5G RB) of consecutive sub-carriers in the frequency domain. Each PRS resource is configured with an RE offset, slot offset, a symbol offset within a slot, and a number of consecutive symbols that the PRS resource may occupy within a slot. The RE offset defines the starting RE offset of the first symbol within a DL PRS resource in frequency. The relative RE offsets of the remaining symbols within a DL PRS resource are defined based on the initial offset. The slot offset is the starting slot of the DL PRS resource with respect to a corresponding resource set slot offset. The symbol offset determines the starting symbol of the DL PRS resource within the starting slot. Transmitted REs may repeat across slots, with each transmission being called a repetition such that there may be multiple repetitions in a PRS resource. The DL PRS resources in a DL PRS resource set are associated with the same TRP and each DL PRS resource has a DL PRS resource ID. A DL PRS resource ID in a DL PRS resource set is associated with a single beam transmitted from a single TRP (although a TRP may transmit one or more beams).

[0096] A PRS resource may also be defined by quasi-co-location and start PRB parameters. A quasi-co-location (QCL) parameter may define any quasi-co-location information of the DL PRS resource with other reference signals. The DL PRS may be configured to be QCL type D with a DL PRS or SS/PBCH (Synchronization Signal/Physical Broadcast Channel) Block from a serving cell or a non-serving cell. The DL PRS may be configured to be QCL type C with an SS/PBCH Block from a serving cell or a non-serving cell. The start PRB parameter defines the starting PRB index of the DL PRS resource with respect to reference Point A. The starting PRB index has a granularity of one PRB and may have a minimum value of 0 and a maximum value of 2176 PRBs.

[0097] A PRS resource set is a collection of PRS resources with the same periodicity, same muting pattern configuration (if any), and the same repetition factor across slots. Every time all repetitions of all PRS resources of the PRS resource set are configured to be transmitted is referred as an "instance". Therefore, an "instance" of a PRS resource set is a specified number of repetitions for each PRS resource and a specified number of PRS resources within the PRS resource set such that once the specified number of repetitions are transmitted for each of the specified number of PRS resources, the

instance is complete. An instance may also be referred to as an "occasion." A DL PRS configuration including a DL PRS transmission schedule may be provided to a UE to facilitate (or even enable) the UE to measure the DL PRS.

[0098] Multiple frequency layers of PRS may be aggregated to provide an effective bandwidth that is larger than any of the bandwidths of the layers individually. Multiple frequency layers of component carriers (which may be consecutive and/or separate) and meeting criteria such as being quasi co-located (QCLed), and having the same antenna port, may be stitched to provide a larger effective PRS bandwidth (for DL PRS and UL PRS) resulting in increased time of arrival measurement accuracy. Stitching comprises combining PRS measurements over individual bandwidth fragments into a unified piece such that the stitched PRS may be treated as having been taken from a single measurement. Being QCLed, the different frequency layers behave similarly, enabling stitching of the PRS to yield the larger effective bandwidth. The larger effective bandwidth, which may be referred to as the bandwidth of an aggregated PRS or the frequency bandwidth of an aggregated PRS, provides for better time-domain resolution (e.g., of TDOA). An aggregated PRS includes a collection of PRS resources and each PRS resource of an aggregated PRS may be called a PRS component, and each PRS component may be transmitted on different component carriers, bands, or frequency layers, or on different portions of the same band.

[0099] RTT positioning is an active positioning technique in that RTT uses positioning signals sent by TRPs to UEs and by UEs (that are participating in RTT positioning) to TRPs. The TRPs may send DL-PRS signals that are received by the UEs and the UEs may send SRS (Sounding Reference Signal) signals that are received by multiple TRPs. A sounding reference signal may be referred to as an SRS or an SRS signal. In 5G multi-RTT, coordinated positioning may be used with the UE sending a single UL-SRS for positioning that is received by multiple TRPs instead of sending a separate UL-SRS for positioning for each TRP. A TRP that participates in multi-RTT will typically search for UEs that are currently camped on that TRP (served UEs, with the TRP being a serving TRP) and also UEs that are camped on neighboring TRPs (neighbor UEs). Neighbor TRPs may be TRPs of a single BTS (Base Transceiver Station) (e.g., gNB), or may be a TRP of one BTS and a TRP of a separate BTS. For RTT positioning, including multi-RTT positioning, the DL-PRS signal and the UL-SRS for positioning signal in a PRS/SRS for positioning signal pair used to determine RTT (and thus used to

determine range between the UE and the TRP) may occur close in time to each other such that errors due to UE motion and/or UE clock drift and/or TRP clock drift are within acceptable limits. For example, signals in a PRS/SRS for positioning signal pair may be transmitted from the TRP and the UE, respectively, within about 10 ms of each other. With SRS for positioning being sent by UEs, and with PRS and SRS for positioning being conveyed close in time to each other, it has been found that radio-frequency (RF) signal congestion may result (which may cause excessive noise, etc.) especially if many UEs attempt positioning concurrently and/or that computational congestion may result at the TRPs that are trying to measure many UEs concurrently.

[00100] RTT positioning may be UE-based or UE-assisted. In UE-based RTT, the UE 200 determines the RTT and corresponding range to each of the TRPs 300 and the position of the UE 200 based on the ranges to the TRPs 300 and known locations of the TRPs 300. In UE-assisted RTT, the UE 200 measures positioning signals and provides measurement information to the TRP 300, and the TRP 300 determines the RTT and range. The TRP 300 provides ranges to a location server, e.g., the server 400, and the server determines the location of the UE 200, e.g., based on ranges to different TRPs 300. The RTT and/or range may be determined by the TRP 300 that received the signal(s) from the UE 200, by this TRP 300 in combination with one or more other devices, e.g., one or more other TRPs 300 and/or the server 400, or by one or more devices other than the TRP 300 that received the signal(s) from the UE 200.

[00101] Various positioning techniques are supported in 5G NR. The NR native positioning methods supported in 5G NR include DL-only positioning methods, UL-only positioning methods, and DL+UL positioning methods. Downlink-based positioning methods include DL-TDOA and DL-AoD. Uplink-based positioning methods include UL-TDOA and UL-AoA. Combined DL+UL-based positioning methods include RTT with one base station and RTT with multiple base stations (multi-RTT).

[00102] A position estimate (e.g., for a UE) may be referred to by other names, such as a location estimate, location, position, position fix, fix, or the like. A position 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 position 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 position 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).

[00103] Accuracy of positioning signal measurements, and thus position estimates based on such measurements, may be improved by increasing processed bandwidth of the positioning signals. For example, if positioning signals of greater bandwidth are transmitted, then greater bandwidths can be processed, yielding a finer resolution in time of arrival measurements, which may translate to more accurate pseudoranges, and thus more accurate position estimates. For example, if more than the standard 272 PRBs may be used for a positioning signal, then accuracy may be increased.

[00104] Referring also to FIG. 5, a UE 500 includes a processor 510, a transceiver 520, and a memory 530 communicatively coupled to each other by a bus 540. The UE 500 may include the components shown in FIG. 5. The UE 500 may include one or more other components such as any of those shown in FIG. 2 such that the UE 200 may be an example of the UE 500. For example, the processor 510 may include one or more of the components of the processor 210. The transceiver 520 may include one or more of the components of the transceiver 215, e.g., the wireless transmitter 242 and the antenna 246, or the wireless receiver 244 and the antenna 246, or the wireless transmitter 242, the wireless receiver 244, and the antenna 246. Also or alternatively, the transceiver 520 may include the wired transmitter 252 and/or the wired receiver 254. The memory 530 may be configured similarly to the memory 211, e.g., including software with processor-readable instructions configured to cause the processor 510 to perform functions.

[00105] The transceiver 520 may include one or more Tx chains 521 configured to process signals, e.g., SRS for positioning, provided by the processor 510 and to transmit the processed signals wirelessly. For example, each of the Tx chain(s) 521 may comprise a power amplifier, a digital to analog converter (DAC), one or more frequency converters, and an appropriate antenna, e.g., for the frequency of the signals to be transmitted. Signals that may be processed by the same Tx chain 521 are called intra-band signals, with each of the Tx chain(s) 521 capable of processing and transmitting respective intra-band signals, with the different intra-band signals being of different frequencies. Signals processed by different chains may incur group delay effects.

[00106] The description herein may refer to the processor 510 performing a function, but this includes other implementations such as where the processor 510 executes software (stored in the memory 530) and/or firmware. The description herein may refer to the UE 500 performing a function as shorthand for one or more appropriate components (e.g., the processor 510 and the memory 530) of the UE 500 performing the function. The processor 510 (possibly in conjunction with the memory 530 and, as appropriate, the transceiver 520) may include an SRS for positioning unit 550. The SRS for positioning unit 550 is discussed further below, and the description may refer to the processor 510 generally, or the UE 500 generally, as performing any of the functions of the SRS for positioning unit 550, with the UE 500 being configured to perform the function(s).

[00107] Referring also to FIG. 6, a network entity 600 includes a processor 610, a transceiver 620, and a memory 630 communicatively coupled to each other by a bus 640. The network entity 600 may include the components shown in FIG. 6. The network entity 600 may include one or more other components such as any of those shown in FIG. 4 such that the server 400 may be an example of the network entity 600. For example, the processor 610 may include one or more of the components of the processor 410. The transceiver 620 may include one or more of the components of the transceiver 415. The memory 630 may be configured similarly to the memory 411, e.g., including software with processor-readable instructions configured to cause the processor 610 to perform functions. Also or alternatively, the network entity 600 may include one or more other components such as any of those shown in FIG. 3 such that the TRP 300 may be an example of the network entity 600. For example, the processor 610 may include one or more of the components of the processor 310. The transceiver 620 may include one or more of the components of the transceiver 315. The memory 630 may be configured similarly to the memory 311, e.g., including software with processor-readable instructions configured to cause the processor 610 to perform functions.

[00108] The transceiver 620 may include one or more Rx chains 621 configured to process wirelessly received signals, e.g., SRS for positioning, and provide the processed signals to the processor 610. For example, each of the Rx chain(s) 621 may comprise an antenna appropriate for the frequency range of received signals, a low-noise amplifier, an analog to digital converter (ADC), and one or more frequency converters.

Signals that may be processed by the same Rx chain 621 are called intra-band signals, with each of the Rx chain(s) 621 capable of receiving and processing respective intra-band signals, with the different intra-band signals being of different frequencies. Signals processed by different chains may incur group delay effects.

[00109] The description herein may refer to the processor 610 performing a function, but this includes other implementations such as where the processor 610 executes software (stored in the memory 630) and/or firmware. The description herein may refer to the server 600 performing a function as shorthand for one or more appropriate components (e.g., the processor 610 and the memory 630) of the server 600 performing the function. The processor 610 (possibly in conjunction with the memory 630 and, as appropriate, the transceiver 620) may include an AD unit 650 (Assistance Data unit). The AD unit 650 is discussed further below, and the description may refer to the processor 610 generally, or the server 600 generally, as performing any of the functions of the AD unit 650, with the server 600 being configured to perform the function(s).

[00110] Referring also to FIG. 7, SRS for positioning may be transmitted over multiple carriers (portions of frequency spectrum), which may be called component carriers (CCs) for use in carrier aggregation in which signals of multiple CCs are aggregated, e.g., to provide greater bandwidth of processed signals. A carrier, in wireless communications, is a portion of continuous spectrum (frequencies). In this example, a first component carrier 710 (CC1) and a second component carrier 720 (CC2) may be used to transmit SRS for positioning. The first component carrier 710 has a bandwidth 740, from a low-end frequency 741 to a high-end frequency 742, and the second component carrier 720 has a bandwidth 750, from a low-end frequency 751 to a high-end frequency 752. Because a carrier is a portion of continuous spectrum, the component carrier 710 may be used interchangeably with the bandwidth 740 and the component carrier 720 may be used interchangeably with the bandwidth 750. A guard band 730 (with a corresponding bandwidth 732) separates the component carriers 710, 720. While FIG. 7 shows only the two component carriers 710, 720, there may be one or more component carriers with bandwidth(s) below (i.e., spanning frequencies lower than) the bandwidth 740 and/or one or more component carriers with bandwidth(s) above (i.e., spanning frequencies higher than) than the bandwidth 750. The component carriers 710, 720 may be called adjacent component carriers because they are consecutive as far as component carriers go, separated by the guard band 730 but with

no other component carrier between them. While historically SRS for positioning spans a multiple of four PRBs and up to 272 PRBs, and frequency hopping is not supported for SRS for positioning, SRS for positioning of greater than 272 PRBs may be configured by the network entity 600 (e.g., the AD unit 650) and used by the UE 500 (e.g.,. the SRS for positioning unit 550). While historically, the guard band 730 would not be used to transmit SRS for positioning, the UE 500 (e.g., the SRS for positioning unit 550) may be configured to transmit SRS for positioning using one or more tones (frequencies) of the guard band 730 and/or the network entity 600 (e.g., the AD unit 650) may be configured to produce an SRS for positioning configuration that includes one or more tones of the guard band 730, e.g., allocates one or more tones of the guard band 730 for SRS for positioning transmission. In NR, the guard band 730 between CCs in intra-band contiguous carrier aggregation (CA) is a multiple of the SCS in adjacent CCs. Tones in adjacent CCs are on an FFT (Fast Fourier Transform) grid of each other. The guard band 730 may include one or more tones or may not exist (i.e., have zero tones). In NR, the guard band 730 in intra-band contiguous CA may or may not be a multiple of a PRB (i.e., may not be a multiple of 12 tones). SRS for positioning may be transmitted in a first tone in a CC or may be shifted such that the first tone in a CC carrying SRS for positioning is not the first tone in the CC. A frequency domain shift indicates the first tone in the CC bandwidth that contains SRS for positioning, and the frequency domain shift may be a multiple of an RB, i.e., a multiple of 12 tones.

[00111] FIG. 7 is an example, and other implementations may be used. For example, while two CCs 710, 720 and one guard band 730 are shown, more than two CCs, e.g., three CCs, may be used with or without a guard band between consecutive CCs. As another example, two tones 735, 736 are shown in the guard band 730, but the guard band 730 (and/or another guard band) may include a different quantity of tones, or no tones, and different guard bands may include different quantities of tones. Also, for simplicity of the figure, only three tones are shown in each of the CCs 710, 720, but one or more of the CCs 710, 720 may include a different quantity of tones for SRS for positioning.

[00112] If SRS for positioning is transmitted within the channel bandwidth of adjacent CCs of intra-band contiguous CA for SRS-Pos bandwidth aggregation, then one or more SRS for positioning tones will be missing in the guard band (if the guard band has a non-zero quantity of tones) between adjacent CCs. For wideband SRS-Pos processing,

to avoid having missing SRS for positioning tones (and thus possibly disparate processing and/or group delay effects), the guard tones may be filled (e.g., by the network entity 600 receiving the SRS for positioning) by interpolating nearby SRS for positioning tones. Such interpolation uses extra calculations in the SRS for positioning processing flow of the network entity 600 and may degrade positioning accuracy if the number of guard tones is large (e.g., 20 or more).

[00113] The UE 500 may be configured to process and transmit, and the network entity 600 may be configured to receive and process, SRS for positioning with a configuration covering aggregated bandwidths. For example, the UE 500 may be configured to process and transmit an SRS for positioning signal with a configuration based on more than one CC, e.g., at least a respective portion of each of two or more CCs, at least a portion of a CC and at least a portion of a guard band, at least a respective portion of each of two or more CCs and a guard band separating each pair of adjacent CCs, etc. As another example, the network entity 600 may be configured to configure, receive, and process an SRS for positioning signal with a configuration based on more than one CC, e.g., at least portions of two or more CCs, at least a portion of a CC and at least a portion of a guard band, at least portions of two or more CCs and at least a respective portion of each of one or more guard bands, etc.

[00114] Referring also to FIG. 8, a single SRS for positioning may be configured across multiple intra-band consecutive CCs (also called contiguous CCs) including one or more guard tones. For example, the AD unit 650 may determine a single SRS for positioning configuration 840 that corresponds to an aggregated bandwidth of a first CC bandwidth 810, a second CC bandwidth 820, and a guard band bandwidth 830 of a guard band (GB). The single SRS for positioning configuration 840 includes a single set of configuration parameters, e.g., comb number, comb offset, starting frequency, ending frequency, etc. A maximum SRS for positioning bandwidth may be extended (e.g., by the network entity 600 and applied by the UE 500) beyond 272 PRBs to span aggregated bandwidths, although such an extended SRS for positioning bandwidth may be a multiple of four PRBs as with legacy configurations. The AD unit 650 may specify a starting position of SRS for positioning resources with respect to the CC having the lowest frequencies of any CCs configured for the SRS for positioning. The AD unit 650 may determine a Zadoff-Chu (ZC) sequence length based on a total number of SRS tones within the configured SRS bandwidth. The UE 500, e.g., the SRS for positioning

unit 550, may be configured to transmit an SRS for positioning signal that includes the aggregated bandwidth of the single SRS for positioning configuration 840. The UE 500, e.g., the SRS for positioning unit 550, may be configured to transmit a partial SRS for positioning signal 850 that is based on the single SRS for positioning configuration 840 but that spans less than the aggregated bandwidth of the single SRS for positioning configuration 840, in this example spanning the same bandwidth as the first CC bandwidth 810. For example, the UE 500 may support transmitting an SRS for positioning signal that is based on the single SRS for positioning configuration 840 but not support transmitting SRS for positioning on a guard band. If a UE does not support transmitting an SRS for positioning signal based on aggregated bandwidth, then the network entity 600, e.g., the AD unit 650, may determine a SRS for positioning configuration that the UE does support (e.g., a legacy configuration) and provide that configuration to the UE.

[00115] Referring also to FIG. 9, an SRS for positioning configuration may be a per-CC configuration with extension into a guard band, e.g., to one or more guard tones. For example, an extended SRS for positioning configuration for one or more CCs, e.g., an extended SRS for positioning configuration 940 corresponding to a first CC bandwidth 910, may be extended by the network entity 600, e.g., the AD unit 650, to include one or more guard tones of a guard band 930, and thus span at least a portion of the first CC bandwidth 910 and at least a portion of the guard band 930. In this example, the extended SRS for positioning configuration 940 corresponds to the first CC bandwidth 910, the bandwidth of the guard band 930, and further frequencies 960 such that the bandwidth corresponding to the extended SRS for positioning configuration 940 is a multiple of four PRBs. The AD unit 650 may determine a ZC-sequence length based on a total number of SRS tones within the configured SRS for positioning bandwidth. The UE 500, e.g., the SRS for positioning unit 550, may be configured to truncate a transmission, e.g., to transmit a truncated SRS for positioning transmission 970 to fit the SRS for positioning transmission into the first CC bandwidth 910 plus the bandwidth of the guard band 930. With the configuration corresponding to a multiple of four PRBs, and with the guard band 930 not necessarily being a multiple of four PRBs, the SRS for positioning configuration may correspond to some of the bandwidth of another CC but the actual transmission of the SRS for positioning signal may be truncated not to extend into the other CC. The SRS for positioning signal may

be produced by the SRS for positioning unit 550 based on the configuration provided by the AD unit 650 (which may correspond to more bandwidth than is used for the actual transmission). The AD unit 650 may configure a per-CC SRS for positioning configuration for a single CC using a legacy SRS for positioning configuration. For SRS for positioning bandwidth aggregation with per-CC configurations, the AD unit 650 may configure, and the SRS for positioning unit 550 may process, SRS for positioning signals with multiple per-CC SRS for positioning resources on intra-band contiguous CCs. Wideband SRS for positioning transmission may be achieved by simultaneous transmission by the SRS for positioning unit 550 of multiple SRS for positioning waveforms on multiple CCs using a single one of the Tx chain(s) 521.

[00116] Referring also to FIG. 10, for a per-carrier positioning signal configuration (also called a per-CC configuration), here a per-carrier SRS for positioning signal configuration, with extension into a guard band, the configuration may be extended into a guard band of lower frequencies than the CC and/or a guard band of higher frequencies than the CC. For extension into a guard band of higher frequencies (than the CC), e.g., extension of a first CC bandwidth 1010 into a bandwidth of a guard band 1030 for an SRS for positioning configuration bandwidth 1040, a starting position (lowest frequency) of an SRS for positioning resource is at least a starting RB of a bandwidth part (BWP) of the first CC bandwidth 1010. This is compatible with the existing 3GPP specification. An SRS for positioning configuration 1050 corresponding to a second CC bandwidth 1020 may be a legacy configuration. Extension into a guard band of higher frequencies than the CC may be achieved by increasing an SRS for positioning resource bandwidth. For extension into a guard band of lower frequencies (than the CC), e.g., extension of a second CC bandwidth 1020 into the bandwidth of the guard band 1030 for an SRS for positioning configuration bandwidth 1060, the guard band 1030 has frequencies lower than a starting RB of the second CC bandwidth 1020, and thus a starting position of the SRS for positioning resources will be before the starting RB of the BWP of the second CC bandwidth 1020. The AD unit 650 may introduce a new parameter, e.g., a new RRC parameter, to indicate a shift of a starting tone of the SRS for positioning into the guard band 1030 of lower frequencies than the corresponding CC, here the second CC bandwidth 1020. The allowable bandwidth of the SRS for positioning may be increased, compared to the legacy allowable bandwidth, to include the bandwidth of a CC and the bandwidth of a guard band. An SRS for

positioning configuration 1070 corresponding to the first CC bandwidth 1010 may be a legacy configuration.

[00117] Using bandwidths including tones inside and outside a carrier bandwidth may provide for processing of increased-bandwidth signals and thus increased positioning accuracy. Transmission of the partial SRS for positioning signal 850 permits the UE 500 to use a configuration for a broader bandwidth without transmission outside of a single carrier. Transmission of SRS for positioning in accordance with the truncated SRS for positioning transmission 970, or the SRS for positioning configuration bandwidth 1040, or the SRS for positioning configuration bandwidth 1060, permits transmission of SRS for positioning that spans a bandwidth of one CC and adjacent guard band.

[00118] Referring also to FIG. 11, a comb configuration of SRS for positioning extending beyond a single CC, e.g., into a guard band and/or into another CC, may be continuous, with one or more comb offsets determined to maintain a contiguous SRS for positioning pattern across aggregated bandwidths. In a contiguous SRS for positioning pattern, for comb M, in any given symbol, there will be M-1 subcarriers between each pair of consecutive sounded subcarriers (for the SRS for positioning signal) regardless of whether the sounded subcarriers are in the same CC, one subcarrier in a CC and one in a guard band, or one subcarrier in a first CC and the other subcarrier in a second CC. For example, a sounding pattern 1100 shows four symbols of transmissions for a last (highest-frequency) RB 1110 of a first CC, a guard band 1130, and a first (lowest-frequency) RB 1120 of a second CC. Solid black rectangles indicate sounded tones (subcarriers). If a single SRS configuration is provided across the CCs (and thus the RBs 1110, 1120) and the guard band 1130, such as the single SRS for positioning configuration 840, then one SRS for positioning configuration may be provided relative to the lower-frequency (lowest-frequency) CC. This single configuration may have on comb size and comb offset combination and be configured with respect to the lower-frequency (lowest-frequency) CC (here the CC corresponding to the RB 1110), and the comb size and comb offset may be applied across the aggregated bandwidth. With per-CC SRS for positioning configurations, the same comb size may be configured by the AD unit 650 across all aggregated CCs. The AD unit 650 may select the comb offset for each CC in a per-CC SRS for positioning resource configuration to maintain continuous SRS for positioning pattern across the aggregated bandwidths. Maintaining

a continuous pattern across the aggregated bandwidths may avoid offset being introduced and thus avoid processing to account for the offset. For per-CC SRS for positioning configurations, the comb offset of a second (or beyond) CC may depend on the number of tones of the guard band (or bands) and comb offset of the lowest-frequency CC of the aggregated CCs. For example, as shown in FIG. 11, the comb size across the RBs 1110, 1120 and the guard band 1130 is 4, the comb offset in the RB 1110 is 0, and the comb offset in the RB 1120 is 2.

[00119] Referring also to FIG. 12, a signal and processing flow 1200 shows communications and SRS for positioning signal transfer between the UE 500 and the network entity 600. The signal and processing flow 1200 includes messages and stages shown and is an example only and not limiting. The flow 1200 may be altered, e.g., by having one or more messages and/or one or more stages added, removed, rearranged, combined, performed concurrently, and/or having one or more messages and/or one or more stages split into multiple messages and/or stages.

[00120] At stage 1210, the UE 500 provides a capability message 1212 to the network entity 600 indicating one or more capabilities of the UE 500 regarding transmission of SRS for positioning, i.e., UL-PRS, over an aggregated bandwidth corresponding to a component carrier and one or more tones outside of the bandwidth of the component carrier. For example, the SRS for positioning unit 550 may transmit the capability message 1212 indicating that the UE 500 may be configured to transmit SRS for positioning over an aggregated bandwidth of intra-band contiguous CCs without SRS for positioning tones on a guard band between adjacent CCs. As another example, the SRS for positioning unit 550 may transmit the capability message 1212 indicating that the UE 500 may be configured to transmit SRS for positioning over an aggregated bandwidth of intra-band contiguous CCs with one or more SRS for positioning tones on a guard band between adjacent CCs. The capability message 1212 may indicate that the UE 500 may transmit SRS for positioning according to a single SRS for positioning resource configuration across aggregated bandwidths including one or more guard tones between adjacent CCs. The capability message 1212 may indicate that the UE 500 may transmit SRS for positioning according to a per-CC SRS for positioning resource configuration with extension into one or more guard tones of one or more corresponding guard bands.

[00121] At stage 1220, the network entity 600, e.g., the AD unit 650, determines a positioning signal configuration, in this example an SRS for positioning configuration (i.e., a UL-PRS configuration). For example, the server 400 may determine the positioning signal configuration such that positioning signal configurations for multiple UEs and/or multiple TRPs are coordinated. As another example, the TRP 300 may determine the positioning signal configuration. The positioning signal configuration, here the SRS for positioning configuration, may be based on the capability of the UE 500 indicated in the capability message 1212. The SRS for positioning configuration may correspond to tones inside and outside of a single CC, e.g., tones in multiple intra-band CCs, a tone in a CC and a tone in a guard band, tones in multiple CCs and a guard band. The network entity 600 may transmit a positioning signal configuration message 1222 to the UE 500 (e.g., by having the server 400 transmit the positioning signal configuration to the TRP 300 which transmits the positioning signal configuration to the UE 500, or by having the TRP 300 transmit the positioning signal configuration to the UE 500).

[00122] At stage 1230, the UE 500 may transmit one or more uplink positioning signals, here UL-PRS 1232, in accordance with the received positioning signal configuration from the network entity 600. For example, the UE 500 may transmit the UL-PRS 1232 according to the full configuration (e.g., per the single SRS for positioning configuration 840), or may transmit a truncated positioning signal (e.g., the truncated SRS for positioning transmission 970) or a partial positioning signal transmission (e.g., the partial SRS for positioning signal 850). The UL-PRS 1232 may, for example, include tones of a single CC based on a configuration corresponding to tones inside and outside the single CC, may include tones of a CC and a guard band, may include tones of multiple intra-band CCs, may include tones of multiple intra-band CCs and one or more guard bands, etc.

[00123] At stage 1240, the network entity 600 may determine position information. For example, the processor 610 may determine one or more positioning signal measurements, one or more pseudoranges, and/or one or more position estimates for the UE 500 (e.g., based on multiple positioning signal measurements of positioning signals transmitted by the UE 500 and received by multiple network entities).

[00124] Referring to FIG. 13, with further reference to FIGS. 1-12, a positioning signal transmission method 1300 includes the stages shown. The method 1300 is, however, an

example only and not limiting. The method 1300 may be altered, e.g., by having one or more stages added, removed, rearranged, combined, performed concurrently, and/or having one or more single stages split into multiple stages.

[00125] At stage 1310, the method 1300 includes receiving, at a user equipment (UE) from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band. For example, the UE 500 may receive the positioning signal configuration message 1222 from the network entity 600 with a positioning signal configuration, and the positioning signal configuration indicating frequencies of at least a respective portion of each of adjacent, intra-band CCs (e.g., the first component carrier 710 and the second component carrier 720) and a guard band (e.g., the guard band 730) separating the CCs, e.g., as discussed with respect to any of FIGS. 7-11. The positioning signal configuration may indicate more than two adjacent CCs and a corresponding guard band between respective pairs of the CCs. The processor 510, possibly in combination with the memory 530, in combination with the transceiver 520 (e.g., the wireless receiver 244 and the antenna 246) may comprise means for receiving the positioning signal configuration.

[00126] At stage 1320, the method 1300 includes transmitting, from the UE to the network entity, the uplink positioning signal based on the positioning signal configuration. For example, the UE 500 may transmit the UL-PRS 1232 based on the positioning signal configuration in the positioning signal configuration message 1222. The processor 510, possibly in combination with the memory 530, in combination with the transceiver 520 (e.g., the wireless transmitter 242 and the antenna 246) may comprise means for transmitting the positioning signal.

[00127] Implementations of the method 1300 may include one or more of the following features. In an example implementation, the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of

the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration. For example, the positioning signal configuration message 1222 may indicate a single set of configuration parameters, e.g., comb number, comb offset, starting frequency, ending frequency, etc., and the UE 500 may transmit the positioning signal in accordance with a configuration such as the single SRS for positioning configuration 840. In another example implementation, the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal within the at least the first portion of the first component carrier. For example the positioning signal configuration message 1222 may indicate a single set of configuration parameters and the UE 500 may transmit a partial positioning signal transmission, e.g., limited to frequencies of the first CC bandwidth 810 such as the partial SRS for positioning signal 850. In another example implementation, the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently. For example, the positioning signal configuration message 1222 may indicate the SRS for positioning configuration bandwidths 1040 and 1050 (or at least a respective portion of each thereof), or the SRS for positioning configuration bandwidths 1060 and 1070 (or at least a respective portion of each thereof), etc., and the UE 500, e.g., the SRS for positioning unit 550 may transmit the UL-PRS 1232 per the SRS for positioning configuration bandwidths 1040 and 1050, or per the SRS for positioning configuration bandwidths 1060 and 1070, etc. (e.g., per the truncated SRS for positioning transmission 970). In a further example implementation, the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb

pattern of the uplink positioning signal is continuous, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier. For example, the positioning signal configuration message 1222 may indicate the same comb number for different per-carrier positioning signal configurations, e.g., for the first CC bandwidth 810 (e.g., the RB 1110), the second CC bandwidth 820 (e.g., the RB 1120), and the guard band bandwidth 830 (e.g., the guard band 1130), and may indicate a comb offset for the second CC bandwidth 820 (and possibly a comb offset for the first CC bandwidth 810) such that the comb pattern across the first CC bandwidth 810 (e.g., the RB 1110), the second CC bandwidth 820 (e.g., the RB 1120), and the guard band bandwidth 830 is continuous (e.g., as in FIG. 11). The UE 500, e.g., the SRS for positioning unit 550 may transmit the UL-PRS 1232 in accordance with the configuration, with a continuous comb pattern, e.g., as shown in FIG. 11.

[00128] Also or alternatively, implementations of the method 1300 may include one or more of the following features. In an example implementation, the method 1300 includes transmitting, from the UE to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers. For example, the UE 500 may transmit the capability message 1212 to the network entity 600 indicating a capability of the UE 500 to transmit positioning signals based on positioning signal configurations corresponding to adjacent component carriers (e.g., at least respective portions thereof). The capability message 1212 may indicate ranges of intra-band frequencies, e.g., ranges of frequencies that each can be processed by a single respective one of the Tx chain(s) 521. The processor 510, possibly in combination with the memory 530, in combination with the transceiver 520 (e.g., the wireless transmitter 242 and the antenna 246) may comprise means for transmitting the capability message. In a further example implementation, the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier

positioning signal configuration corresponding to the prospective aggregated bandwidth. For example, the capability message 1212 may indicate a capability to transmit positioning signals in accordance with the single SRS for positioning configuration 840 (e.g., even if the positioning signal is transmitted using less than a full bandwidth indicated by the single SRS for positioning configuration 840). In another further example implementation, the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers. For example, the capability message 1212 may indicate a capability to transmit positioning signals in accordance with, e.g., the SRS for positioning configuration bandwidths 1040 and 1050, or the SRS for positioning configuration bandwidths 1060 and 1070.

[00129] Referring to FIG. 14, with further reference to FIGS. 1-12, a positioning signal configuration providing method 1400 includes the stages shown. The method 1400 is, however, an example only and not limiting. The method 1400 may be altered, e.g., by having one or more stages added, removed, rearranged, combined, performed concurrently, and/or having one or more single stages split into multiple stages.

[00130] At stage 1410, the method 1400 includes determining, at a network entity, an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band. For example, the network entity 600, e.g., the AD unit 650, may determine a UL-PRS configuration at stage 1220, with the configuration corresponding to adjacent, intra-band component carriers (e.g., the component carriers 710, 720) and a guard band (e.g., the guard band 730). The processor 610, possibly in combination with the memory 630, may comprise means for determining the uplink positioning signal configuration.

[00131] At stage 1420, the method 1400 includes transmitting, from the network entity to a user equipment, the uplink positioning signal configuration. For example, at stage

1220 the network entity 600 may transmit the positioning signal configuration message 1222 to the UE 500 (e.g., directly and/or via one or more intermediaries such as one or more TRPs). The processor 610, possibly in combination with the memory 630, in combination with the transceiver 620, may comprise means for transmitting the uplink positioning signal configuration. For example, the processor 310, possibly in combination with the memory 311 (e.g., the software 312), in combination with the wireless transmitter 342 and the antenna 346 may comprise means for transmitting the uplink positioning signal configuration. Also or alternatively, the processor 410, possibly in combination with the memory 411 (e.g., the software 412), in combination with the transceiver 415 (e.g., the wireless transmitter 442 and the antenna 446, and/or the wired transmitter 452), may comprise means for transmitting the uplink positioning signal configuration.

[00132] Implementations of the method 1400 may include one or more of the following features. In an example implementation, the uplink positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier. For example, the positioning signal configuration message 1222 may indicate a single set of configuration parameters, e.g., comb number, comb offset, starting frequency, ending frequency, etc., and the UE 500 may transmit the positioning signal in accordance with a configuration such as the single SRS for positioning configuration 840. In another example implementation, the uplink positioning signal configuration comprises a first per-carrier uplink positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier uplink positioning signal configuration, indicating the at least the second portion of the second component carrier. For example, the positioning signal configuration message 1222 may indicate the SRS for positioning configuration bandwidths 1040 and 1050 (or at least a respective portion of each thereof), or the SRS for positioning configuration bandwiths 1060 and 1070 (or at least a respective portion of each thereof), etc. In a further example implementation, the first per-carrier positioning signal configuration includes a radio resource control parameter indicating a starting frequency, of the uplink positioning signal, in the guard band with the guard band spanning frequencies below the first component carrier. For example, the

positioning signal configuration message 1222 (or a separate message) may indicate (e.g., in an RRC parameter) a starting frequency where the starting frequency is in a guard band of a lower frequency than the corresponding CC, e.g., for the SRS for positioning configuration bandwidth 1060. In another further example implementation, the first per-carrier uplink positioning signal configuration indicates a comb number, and the second per-carrier uplink positioning signal configuration indicates the comb number and a comb offset such that a comb pattern based on the first per-carrier uplink positioning signal configuration and the second per-carrier uplink positioning signal configuration is continuous across the first portion of the first component carrier, the guard band, and the second portion of the second component carrier. For example, the positioning signal configuration message 1222 may indicate the same comb number for different per-carrier positioning signal configurations, e.g., for the first CC bandwidth 810 (e.g., the RB 1110), the second CC bandwidth 820 (e.g., the RB 1120), and the guard band bandwidth 830 (e.g., the guard band 1130), and may indicate a comb offset for the second CC bandwidth 820 (and possibly a comb offset for the first CC bandwidth 810) such that the comb pattern across the first CC bandwidth 810 (e.g., the RB 1110), the second CC bandwidth 820 (e.g., the RB 1120), and the guard band bandwidth 830 is continuous (e.g., as in FIG. 11).

[00133] Also or alternatively, implementations of the method 1400 may include one or more of the following features. In an example implementation, transmitting the uplink positioning signal configuration comprises transmitting the uplink positioning signal configuration based on receiving, from the user equipment, a capability message indicating a capability of the user equipment to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers. For example, the network entity 600 may receive the capability message 1212 from the UE 500 and transmit the positioning signal configuration message 1222 based on (e.g., in response to) receiving the capability message 1212. The capability message may indicate component carriers, a respective portion of one or more respective component carriers, one or more ranges of intra-band frequencies, etc. of a prospective uplink positioning signal (e.g., an uplink positioning signal that the UE 500 is capable of transmitting in adjacent component carriers concurrently per the indicated capability). The processor

610, possibly in combination with the memory 630, in combination with the transceiver 620, may comprise means for transmitting the uplink positioning signal configuration. For example, the processor 310, possibly in combination with the memory 311 (e.g., the software 312), in combination with the wireless receiver 344 and the antenna 346 may comprise means for transmitting the uplink positioning signal configuration based on receiving the capability message. Also or alternatively, the processor 410, possibly in combination with the memory 411 (e.g., the software 412), in combination with the transceiver 415 (e.g., the wireless receiver 444 and the antenna 446, and/or the wired transmitter 454), may comprise means for transmitting the uplink positioning signal configuration based on receiving the capability message.

[00134] Referring to FIG. 15, with further reference to FIGS. 1-12, a positioning signal configuration providing method 1500 includes the stages shown. The method 1500 is, however, an example only and not limiting. The method 1500 may be altered, e.g., by having one or more stages added, removed, rearranged, combined, performed concurrently, and/or having one or more single stages split into multiple stages.

[00135] At stage 1510, the method 1500 includes determining, at a network entity, an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band, the uplink positioning signal configuration including a comb number and a comb offset for the at least the second portion of the second component carrier based on the comb number and the guard band. For example, the network entity 600, e.g., the AD unit 650, may determine a UL-PRS configuration at stage 1220, with the configuration corresponding to adjacent, intra-band component carriers (e.g., the component carriers 710, 720) and a guard band (e.g., the guard band 730). The comb offset corresponding to the higher-frequency component carrier may be determined based on the comb number, the number of tones in the guard band, and the comb offset (if any) of the lower-frequency component carrier. The comb offset corresponding to the higher-frequency component carrier may be determined according to

$$CO_H = (CN - REM(GT/CN)) + CO_L \qquad (1)$$

where CO_H is the comb offset of a higher-frequency component carrier in a pair of adjacent component carriers, CN is the comb number, REM is a remainder function yielding an integer number of the remainder of an operand quotient, GT is the number of tones in the guard band separating the adjacent component carriers, and C_L is the comb offset of a higher-frequency component carrier in a pair of adjacent component carriers. Equation (1) may be applied to any pair of adjacent component carriers corresponding to a positioning signal configuration (e.g., corresponding to two or more component carriers). The processor 610, possibly in combination with the memory 630, may comprise means for determining the uplink positioning signal configuration.

[00136] At stage 1520, the method 1500 includes transmitting, from the network entity to a user equipment, the uplink positioning signal configuration. For example, at stage 1220 the network entity 600 may transmit the positioning signal configuration message 1222 to the UE 500 (e.g., directly and/or via one or more intermediaries such as one or more TRPs). The processor 610, possibly in combination with the memory 630, in combination with the transceiver 620, may comprise means for transmitting the uplink positioning signal configuration. For example, the processor 310, possibly in combination with the memory 311 (e.g., the software 312), in combination with the wireless transmitter 342 and the antenna 346 may comprise means for transmitting the uplink positioning signal configuration. Also or alternatively, the processor 410, possibly in combination with the memory 411 (e.g., the software 412), in combination with the transceiver 415 (e.g., the wireless transmitter 442 and the antenna 446, and/or the wired transmitter 452), may comprise means for transmitting the uplink positioning signal configuration.

[00137] **Implementation examples**

[00138] Implementation examples are provided in the following numbered clauses.

[00139] Clause 1. A user equipment (UE) comprising:

a transceiver;

a memory; and

a processor communicatively coupled to the transceiver and the memory and configured to:

receive, via the transceiver from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second

portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmit, via the transceiver to the network entity, the uplink positioning signal based on the positioning signal configuration.

[00140] Clause 2. The UE of clause 1, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor is configured to transmit the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

[00141] Clause 3. The UE of clause 1, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor is configured to transmit the uplink positioning signal within the at least the first portion of the first component carrier.

[00142] Clause 4. The UE of clause 1, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein the processor is configured to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

[00143] Clause 5. The UE of clause 4, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein the processor is configured to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern

across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00144] Clause 6. The UE of clause 1, wherein the processor is configured to transmit, via the transceiver to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00145] Clause 7. The UE of clause 6, wherein the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

[00146] Clause 8. The UE of clause 6, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

[00147] Clause 9. A positioning signal transmission method comprising:

receiving, at a user equipment (UE) from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmitting, from the UE to the network entity, the uplink positioning signal based on the positioning signal configuration.

[00148] Clause 10. The positioning signal transmission method of clause 9, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal

comprises transmitting the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

[00149] Clause 11. The positioning signal transmission method of clause 9, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal within the at least the first portion of the first component carrier.

[00150] Clause 12. The positioning signal transmission method of clause 9, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

[00151] Clause 13. The positioning signal transmission method of clause 12, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00152] Clause 14. The positioning signal transmission method of clause 9, further comprising transmitting, from the UE to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective

adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00153] Clause 15. The positioning signal transmission method of clause 14, wherein the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

[00154] Clause 16. The positioning signal transmission method of clause 14, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

[00155] Clause 17. A user equipment (UE) comprising:

means for receiving, from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

means for transmitting, to the network entity, the uplink positioning signal based on the positioning signal configuration.

[00156] Clause 18. The UE of clause 17, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

[00157] Clause 19. The UE of clause 17, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier,

the guard band, and the at least the second portion of the second component carrier, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal within the at least the first portion of the first component carrier.

[00158] Clause 20. The UE of clause 17, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

[00159] Clause 21. The UE of clause 20, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00160] Clause 22. The UE of clause 17, further comprising means for transmitting, to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00161] Clause 23. The UE of clause 22, wherein the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

[00162] Clause 24. The UE of clause 22, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

[00163] Clause 25. A non-transitory, processor-readable storage medium comprising processor-readable instructions to cause a processor of a user equipment (UE) to:

receive, from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmit, to the network entity, the uplink positioning signal based on the positioning signal configuration.

[00164] Clause 26. The non-transitory, processor-readable storage medium of clause 25, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

[00165] Clause 27. The non-transitory, processor-readable storage medium of clause 25, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise

processor-readable instructions to cause the processor to transmit the uplink positioning signal within the at least the first portion of the first component carrier.

[00166] Clause 28. The non-transitory, processor-readable storage medium of clause 25, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

[00167] Clause 29. The non-transitory, processor-readable storage medium of clause 28, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00168] Clause 30. The non-transitory, processor-readable storage medium of clause 25, further comprising processor-readable instructions to cause the processor to transmit, to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00169] Clause 31. The non-transitory, processor-readable storage medium of clause 30, wherein the capability message indicates a second capability of the UE to transmit

the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

[00170] Clause 32. The non-transitory, processor-readable storage medium of clause 30, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

[00171] Clause 33. A network entity comprising:

a transmitter;

a memory; and

a processor communicatively coupled to the transmitter and the memory and configured to:

determine an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmit, via the transmitter to a user equipment, the uplink positioning signal configuration.

[00172] Clause 34. The network entity of clause 33, wherein the uplink positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00173] Clause 35. The network entity of clause 33, wherein the uplink positioning signal configuration comprises a first per-carrier uplink positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier uplink positioning signal configuration, indicating the at least the second portion of the second component carrier.

[00174] Clause 36. The network entity of clause 35, wherein the first per-carrier positioning signal configuration includes a radio resource control parameter indicating a

starting frequency, of the uplink positioning signal, in the guard band with the guard band spanning frequencies below the first component carrier.

[00175] Clause 37. The network entity of clause 35, wherein the first per-carrier uplink positioning signal configuration indicates a comb number, and the second per-carrier uplink positioning signal configuration indicates the comb number and a comb offset such that a comb pattern based on the first per-carrier uplink positioning signal configuration and the second per-carrier uplink positioning signal configuration is continuous across the first portion of the first component carrier, the guard band, and the second portion of the second component carrier.

[00176] Clause 38. The network entity of clause 33, further comprising a receiver communicatively coupled to the processor, wherein the processor is configured to transmit the uplink positioning signal configuration based on receiving, via the receiver from the user equipment, a capability message indicating a capability of the user equipment to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00177] Clause 39. A positioning signal configuration providing method comprising:

determining, at a network entity, an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmitting, from the network entity to a user equipment, the uplink positioning signal configuration.

[00178] Clause 40. The positioning signal configuration providing method of clause 39, wherein the uplink positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00179] Clause 41. The positioning signal configuration providing method of clause 39, wherein the uplink positioning signal configuration comprises a first per-carrier uplink positioning signal configuration, indicating the at least the first portion of the

first component carrier and the guard band, and a second per-carrier uplink positioning signal configuration, indicating the at least the second portion of the second component carrier.

[00180] Clause 42. The positioning signal configuration providing method of clause 41, wherein the first per-carrier positioning signal configuration includes a radio resource control parameter indicating a starting frequency, of the uplink positioning signal, in the guard band with the guard band spanning frequencies below the first component carrier.

[00181] Clause 43. The positioning signal configuration providing method of clause 41, wherein the first per-carrier uplink positioning signal configuration indicates a comb number, and the second per-carrier uplink positioning signal configuration indicates the comb number and a comb offset such that a comb pattern based on the first per-carrier uplink positioning signal configuration and the second per-carrier uplink positioning signal configuration is continuous across the first portion of the first component carrier, the guard band, and the second portion of the second component carrier.

[00182] Clause 44. The positioning signal configuration providing method of clause 39, wherein transmitting the uplink positioning signal configuration comprises transmitting the uplink positioning signal configuration based on receiving, from the user equipment, a capability message indicating a capability of the user equipment to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00183] Clause 45. A network entity comprising:

means for determining an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

means for transmitting, to a user equipment, the uplink positioning signal configuration.

[00184] Clause 46. The network entity of clause 45, wherein the uplink positioning signal configuration comprises a multi-carrier positioning signal configuration

indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00185] Clause 47. The network entity of clause 45, wherein the uplink positioning signal configuration comprises a first per-carrier uplink positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier uplink positioning signal configuration, indicating the at least the second portion of the second component carrier.

[00186] Clause 48. The network entity of clause 47, wherein the first per-carrier positioning signal configuration includes a radio resource control parameter indicating a starting frequency, of the uplink positioning signal, in the guard band with the guard band spanning frequencies below the first component carrier.

[00187] Clause 49. The network entity of clause 47, wherein the first per-carrier uplink positioning signal configuration indicates a comb number, and the second per-carrier uplink positioning signal configuration indicates the comb number and a comb offset such that a comb pattern based on the first per-carrier uplink positioning signal configuration and the second per-carrier uplink positioning signal configuration is continuous across the first portion of the first component carrier, the guard band, and the second portion of the second component carrier.

[00188] Clause 50. The network entity of clause 45, wherein the means for transmitting the uplink positioning signal configuration comprise means for transmitting the uplink positioning signal configuration based on receiving, from the user equipment, a capability message indicating a capability of the user equipment to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00189] Clause 51. A non-transitory, processor-readable storage medium comprising processor-readable instructions to cause a processor of a network entity to:

determine an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmit, to a user equipment, the uplink positioning signal configuration.

[00190] Clause 52. The non-transitory, processor-readable storage medium of clause 51, wherein the uplink positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

[00191] Clause 53. The non-transitory, processor-readable storage medium of clause 51, wherein the uplink positioning signal configuration comprises a first per-carrier uplink positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier uplink positioning signal configuration, indicating the at least the second portion of the second component carrier.

[00192] Clause 54. The non-transitory, processor-readable storage medium of clause 53, wherein the first per-carrier positioning signal configuration includes a radio resource control parameter indicating a starting frequency, of the uplink positioning signal, in the guard band with the guard band spanning frequencies below the first component carrier.

[00193] Clause 55. The non-transitory, processor-readable storage medium of clause 53, wherein the first per-carrier uplink positioning signal configuration indicates a comb number, and the second per-carrier uplink positioning signal configuration indicates the comb number and a comb offset such that a comb pattern based on the first per-carrier uplink positioning signal configuration and the second per-carrier uplink positioning signal configuration is continuous across the first portion of the first component carrier, the guard band, and the second portion of the second component carrier.

[00194] Clause 56. The non-transitory, processor-readable storage medium of clause 51, wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal configuration comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal configuration based on receiving, from the user equipment, a capability message indicating a capability of the user equipment to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

[00195] **Other considerations**

[00196] Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software and computers, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or a combination of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[00197] As used herein, the singular forms "a," "an," and "the" include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "includes," and/or "including," as used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[00198] Also, as used herein, "or" as used in a list of items (possibly prefaced by "at least one of" or prefaced by "one or more of") indicates a disjunctive list such that, for example, a list of "at least one of A, B, or C," or a list of "one or more of A, B, or C" or a list of "A or B or C" means A, or B, or C, or AB (A and B), or AC (A and C), or BC (B and C), or ABC (i.e., A and B and C), or combinations with more than one feature (e.g., AA, AAB, ABBC, etc.). Thus, a recitation that an item, e.g., a processor, is configured to perform a function regarding at least one of A or B, or a recitation that an item is configured to perform a function A or a function B, means that the item may be configured to perform the function regarding A, or may be configured to perform the function regarding B, or may be configured to perform the function regarding A and B. For example, a phrase of "a processor configured to measure at least one of A or B" or "a processor configured to measure A or measure B" means that the processor may be configured to measure A (and may or may not be configured to measure B), or may be configured to measure B (and may or may not be configured to measure A), or may be configured to measure A and measure B (and may be configured to select which, or both, of A and B to measure). Similarly, a recitation of a means for measuring at least one of A or B includes means for measuring A (which may or may not be able to measure B), or means for measuring B (and may or may not be configured to measure A), or means for measuring A and B (which may be able to select which, or both, of A

and B to measure). As another example, a recitation that an item, e.g., a processor, is configured to at least one of perform function X or perform function Y means that the item may be configured to perform the function X, or may be configured to perform the function Y, or may be configured to perform the function X and to perform the function Y. For example, a phrase of "a processor configured to at least one of measure X or measure Y" means that the processor may be configured to measure X (and may or may not be configured to measure Y), or may be configured to measure Y (and may or may not be configured to measure X), or may be configured to measure X and to measure Y (and may be configured to select which, or both, of X and Y to measure).

[00199] As used herein, unless otherwise stated, a statement that a function or operation is "based on" an item or condition means that the function or operation is based on the stated item or condition and may be based on one or more items and/or conditions in addition to the stated item or condition.

[00200] Substantial variations may be made in accordance with specific requirements. For example, customized hardware might also be used, and/or particular elements might be implemented in hardware, software (including portable software, such as applets, etc.) executed by a processor, or both. Further, connection to other computing devices such as network input/output devices may be employed. Components, functional or otherwise, shown in the figures and/or discussed herein as being connected or communicating with each other are communicatively coupled unless otherwise noted. That is, they may be directly or indirectly connected to enable communication between them.

[00201] The systems and devices discussed above are examples. Various configurations may omit, substitute, or add various procedures or components as appropriate. For instance, features described with respect to certain configurations may be combined in various other configurations. Different aspects and elements of the configurations may be combined in a similar manner. Also, technology evolves and, thus, many of the elements are examples and do not limit the scope of the disclosure or claims.

[00202] A wireless communication system is one in which communications are conveyed wirelessly, i.e., by electromagnetic and/or acoustic waves propagating through atmospheric space rather than through a wire or other physical connection, between wireless communication devices. A wireless communication system (also

called a wireless communications system, a wireless communication network, or a wireless communications network) may not have all communications transmitted wirelessly, but is configured to have at least some communications transmitted wirelessly. Further, the term "wireless communication device," or similar term, does not require that the functionality of the device is exclusively, or even primarily, for communication, or that communication using the wireless communication device is exclusively, or even primarily, wireless, or that the device be a mobile device, but indicates that the device includes wireless communication capability (one-way or two-way), e.g., includes at least one radio (each radio being part of a transmitter, receiver, or transceiver) for wireless communication.

[00203] Specific details are given in the description herein to provide a thorough understanding of example configurations (including implementations). However, configurations may be practiced without these specific details. For example, well-known circuits, processes, algorithms, structures, and techniques have been shown without unnecessary detail in order to avoid obscuring the configurations. The description herein provides example configurations, and does not limit the scope, applicability, or configurations of the claims. Rather, the preceding description of the configurations provides a description for implementing described techniques. Various changes may be made in the function and arrangement of elements.

[00204] The terms "processor-readable medium," "machine-readable medium," and "computer-readable medium," as used herein, refer to any medium that participates in providing data that causes a machine to operate in a specific fashion. Using a computing platform, various processor-readable media might be involved in providing instructions/code to processor(s) for execution and/or might be used to store and/or carry such instructions/code (e.g., as signals). In many implementations, a processor-readable medium is a physical and/or tangible storage medium. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media include, for example, optical and/or magnetic disks. Volatile media include, without limitation, dynamic memory.

[00205] Having described several example configurations, various modifications, alternative constructions, and equivalents may be used. For example, the above elements may be components of a larger system, wherein other rules may take precedence over or otherwise modify the application of the disclosure. Also, a number

of operations may be undertaken before, during, or after the above elements are considered. Accordingly, the above description does not bound the scope of the claims.

[00206] Unless otherwise indicated, "about" and/or "approximately" as used herein when referring to a measurable value such as an amount, a temporal duration, and the like, encompasses variations of ±20% or ±10%, ±5%, or +0.1% from the specified value, as appropriate in the context of the systems, devices, circuits, methods, and other implementations described herein. Unless otherwise indicated, "substantially" as used herein when referring to a measurable value such as an amount, a temporal duration, a physical attribute (such as frequency), and the like, also encompasses variations of ±20% or ±10%, ±5%, or +0.1% from the specified value, as appropriate in the context of the systems, devices, circuits, methods, and other implementations described herein.

[00207] A statement that a value exceeds (or is more than or above) a first threshold value is equivalent to a statement that the value meets or exceeds a second threshold value that is slightly greater than the first threshold value, e.g., the second threshold value being one value higher than the first threshold value in the resolution of a computing system. A statement that a value is less than (or is within or below) a first threshold value is equivalent to a statement that the value is less than or equal to a second threshold value that is slightly lower than the first threshold value, e.g., the second threshold value being one value lower than the first threshold value in the resolution of a computing system.

CLAIMS:

1. A user equipment (UE) comprising:

a transceiver;

a memory; and

a processor communicatively coupled to the transceiver and the memory and configured to:

receive, via the transceiver from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmit, via the transceiver to the network entity, the uplink positioning signal based on the positioning signal configuration.

2. The UE of claim 1, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor is configured to transmit the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

3. The UE of claim 1, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor is configured to transmit the uplink positioning signal within the at least the first portion of the first component carrier.

4. The UE of claim 1, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein the processor is configured to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

5. The UE of claim 4, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein the processor is configured to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

6. The UE of claim 1, wherein the processor is configured to transmit, via the transceiver to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

7. The UE of claim 6, wherein the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

8. The UE of claim 6, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first

respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

9. A positioning signal transmission method comprising:

receiving, at a user equipment (UE) from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmitting, from the UE to the network entity, the uplink positioning signal based on the positioning signal configuration.

10. The positioning signal transmission method of claim 9, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

11. The positioning signal transmission method of claim 9, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal within the at least the first portion of the first component carrier.

12. The positioning signal transmission method of claim 9, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

13. The positioning signal transmission method of claim 12, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein transmitting the uplink positioning signal comprises transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

14. The positioning signal transmission method of claim 9, further comprising transmitting, from the UE to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

15. The positioning signal transmission method of claim 14, wherein the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

16. The positioning signal transmission method of claim 14, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

17. A user equipment (UE) comprising:

means for receiving, from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

means for transmitting, to the network entity, the uplink positioning signal based on the positioning signal configuration.

18. The UE of claim 17, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

19. The UE of claim 17, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting

the uplink positioning signal within the at least the first portion of the first component carrier.

20. The UE of claim 17, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

21. The UE of claim 20, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein the means for transmitting the uplink positioning signal comprise means for transmitting the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

22. The UE of claim 17, further comprising means for transmitting, to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

23. The UE of claim 22, wherein the capability message indicates a second capability of the UE to transmit the prospective uplink positioning signal according to a single multi-carrier positioning signal configuration corresponding to the prospective aggregated bandwidth.

24. The UE of claim 22, wherein the capability message indicates a third capability of the UE to transmit prospective uplink positioning signal concurrently in accordance with: a first per-carrier positioning signal configuration, indicating a first respective portion of a first of the prospective adjacent, intra-band component carriers and the respective guard band; and a second per-carrier positioning signal configuration, indicating a second respective portion of a second of the prospective adjacent, intra-band component carriers.

25. A non-transitory, processor-readable storage medium comprising processor-readable instructions to cause a processor of a user equipment (UE) to:

receive, from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band; and

transmit, to the network entity, the uplink positioning signal based on the positioning signal configuration.

26. The non-transitory, processor-readable storage medium of claim 25, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal spanning the aggregated bandwidth of the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier based on the multi-carrier positioning signal configuration.

27. The non-transitory, processor-readable storage medium of claim 25, wherein the positioning signal configuration comprises a multi-carrier positioning signal configuration indicating a single set of configuration parameters for the at least the first

portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal within the at least the first portion of the first component carrier.

28. The non-transitory, processor-readable storage medium of claim 25, wherein the positioning signal configuration comprises a first per-carrier positioning signal configuration, indicating the at least the first portion of the first component carrier and the guard band, and a second per-carrier positioning signal configuration, indicating the at least the second portion of the second component carrier, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration concurrently.

29. The non-transitory, processor-readable storage medium of claim 28, wherein the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration indicate a same comb number, and the second per-carrier positioning signal configuration indicates a comb offset such that a comb pattern of the uplink positioning signal is continuous, and wherein the processor-readable instructions to cause the processor to transmit the uplink positioning signal comprise processor-readable instructions to cause the processor to transmit the uplink positioning signal in accordance with the first per-carrier positioning signal configuration and the second per-carrier positioning signal configuration with a continuous comb pattern across the at least the first portion of the first component carrier, the guard band, and the at least the second portion of the second component carrier.

30. The non-transitory, processor-readable storage medium of claim 25, further comprising processor-readable instructions to cause the processor to transmit, to the network entity, a capability message indicating a first capability of the UE to transmit a prospective uplink positioning signal having a prospective aggregated bandwidth of at

least respective portions of prospective adjacent, intra-band component carriers and a respective guard band between the prospective adjacent, intra-band component carriers.

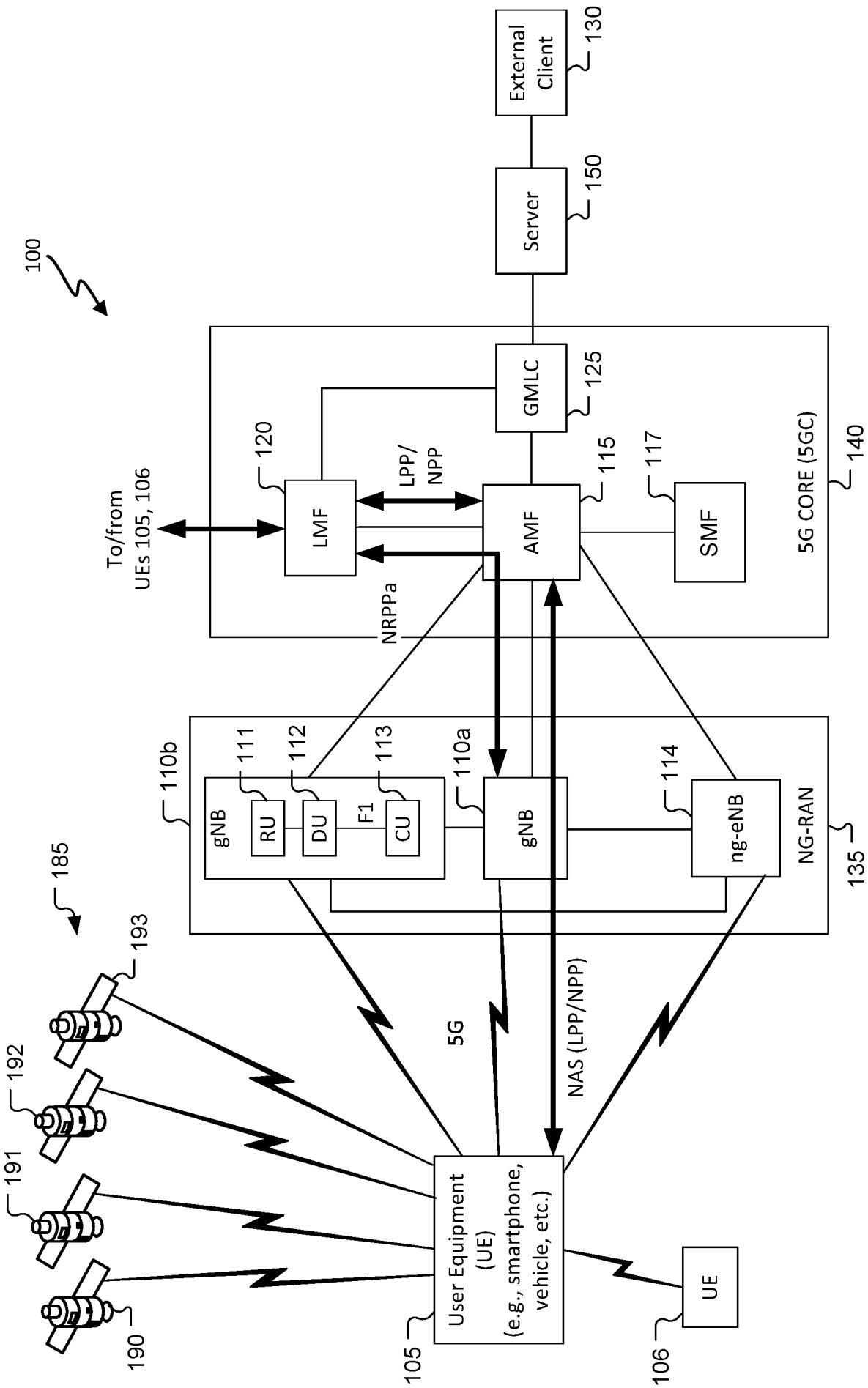

100
External Client
130
Server
150
GMLC
125
LMF
120
LPP/ NPP
AMF
115
SMF
117
5G CORE (5GC)
140
To/from UEs 105, 106
NRPPa
110b
gNB
RU
111
DU
112
F1
CU
113
110a
gNB
114
ng-eNB
NG-RAN
135
185
193
192
191
190
5G
NAS (LPP/NPP)
User Equipment (UE) (e.g., smartphone, vehicle, etc.)
105
UE
106

FIG. 1

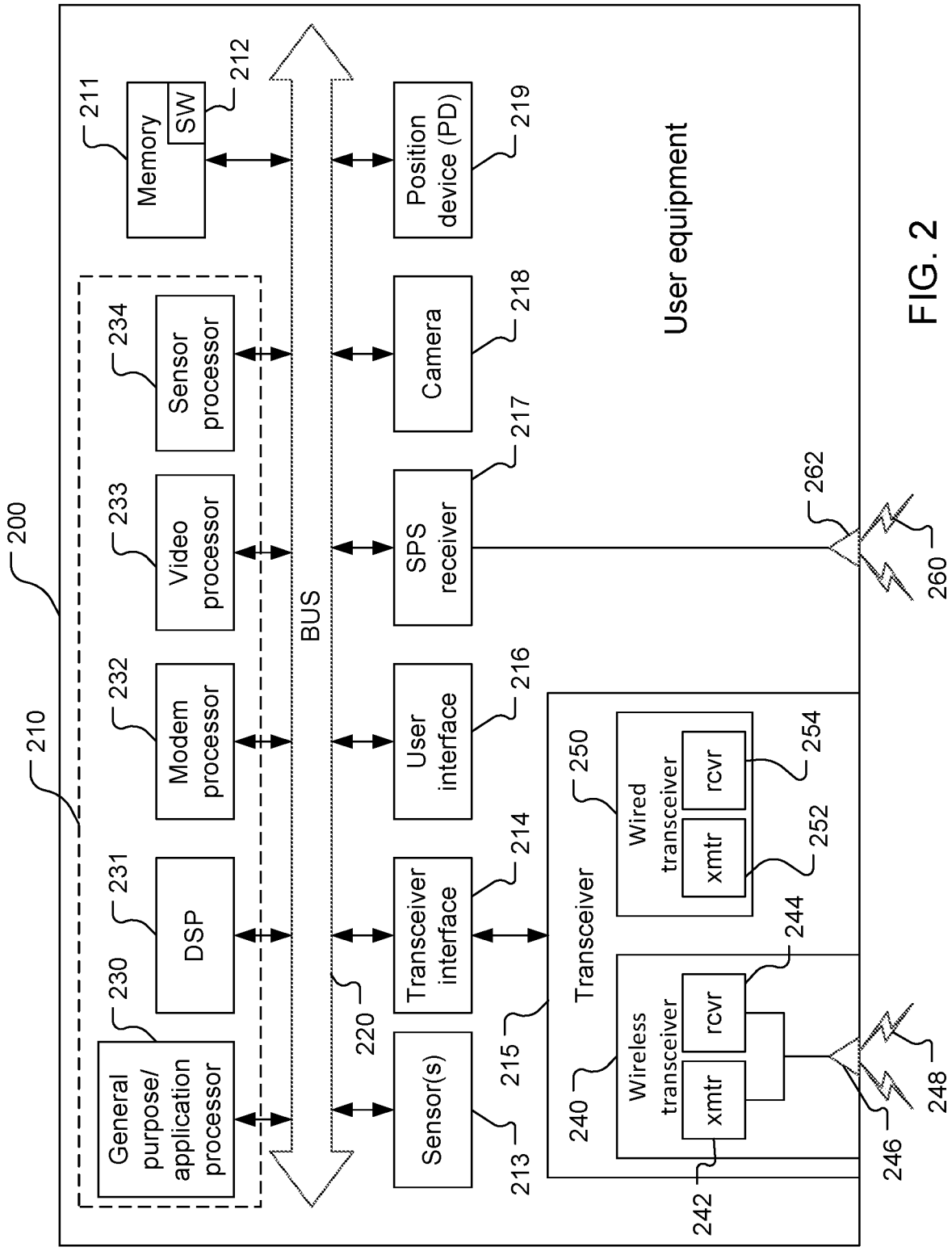

User equipment
200
210
General purpose/ application processor
230
DSP
231
Modem processor
232
Video processor
233
Sensor processor
234
BUS
Memory
SW
211
212
Position device (PD)
219
Camera
218
SPS receiver
217
User interface
216
Transceiver interface
214
Sensor(s)
213
220
215
Transceiver
240
Wireless transceiver
xmtr
rcvr
242
244
Wired transceiver
250
xmtr
rcvr
252
254
246
248
260
262

FIG. 2

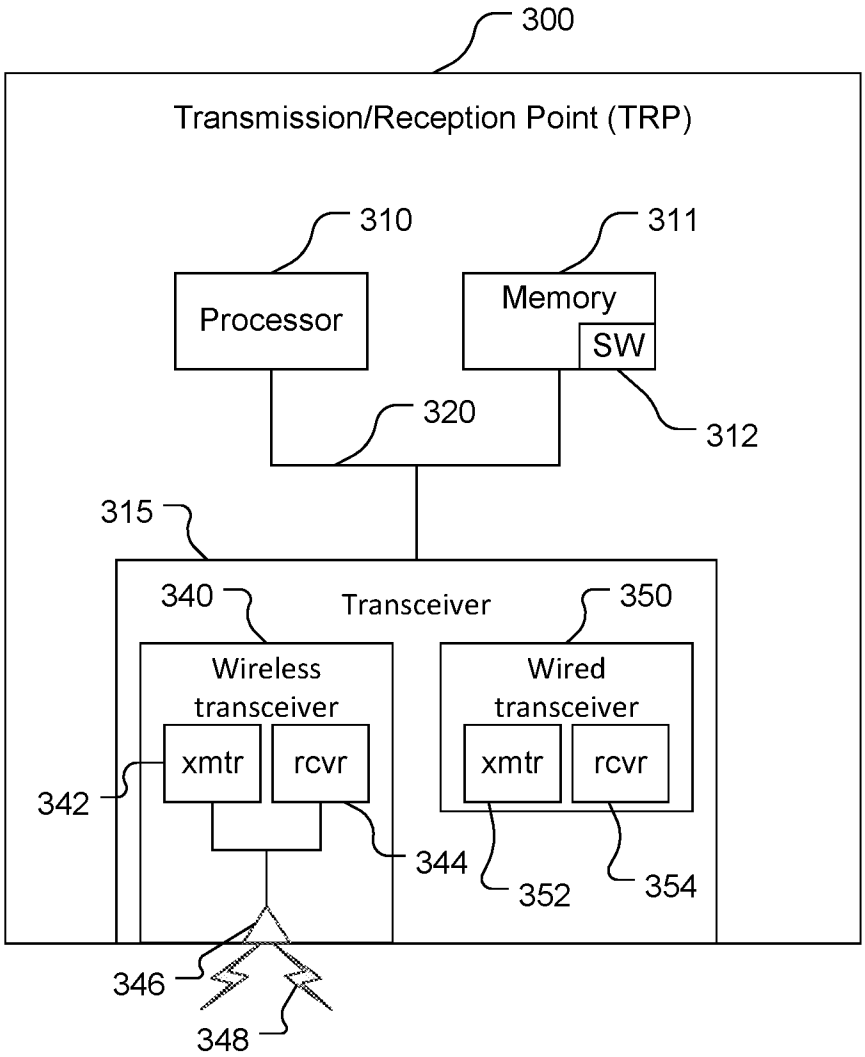

300
Transmission/Reception Point (TRP)
310
Processor
311
Memory
SW
312
320
315
340
Transceiver
350
Wireless transceiver
xmtr
rcvr
342
344
Wired transceiver
xmtr
rcvr
352
354
346
348

FIG. 3

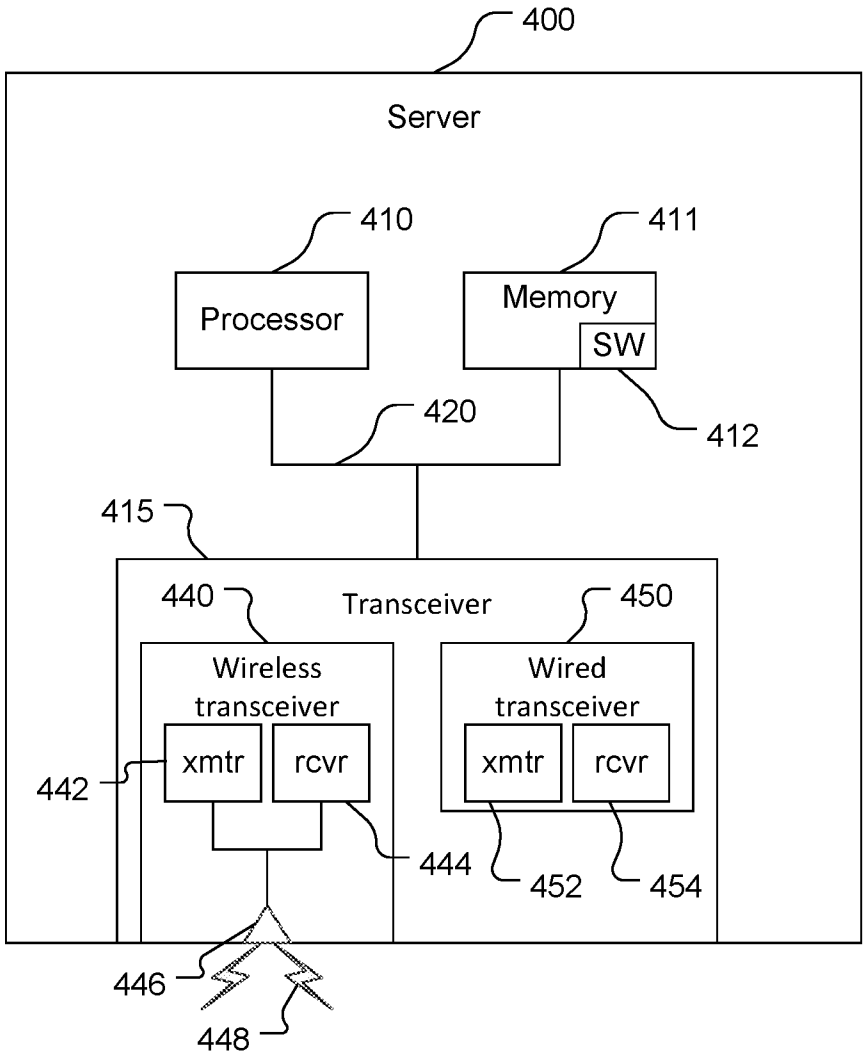

400
Server
410
Processor
411
Memory
SW
412
420
415
440
Transceiver
450
Wireless transceiver
xmtr
rcvr
442
444
Wired transceiver
xmtr
rcvr
452
454
446
448

FIG. 4

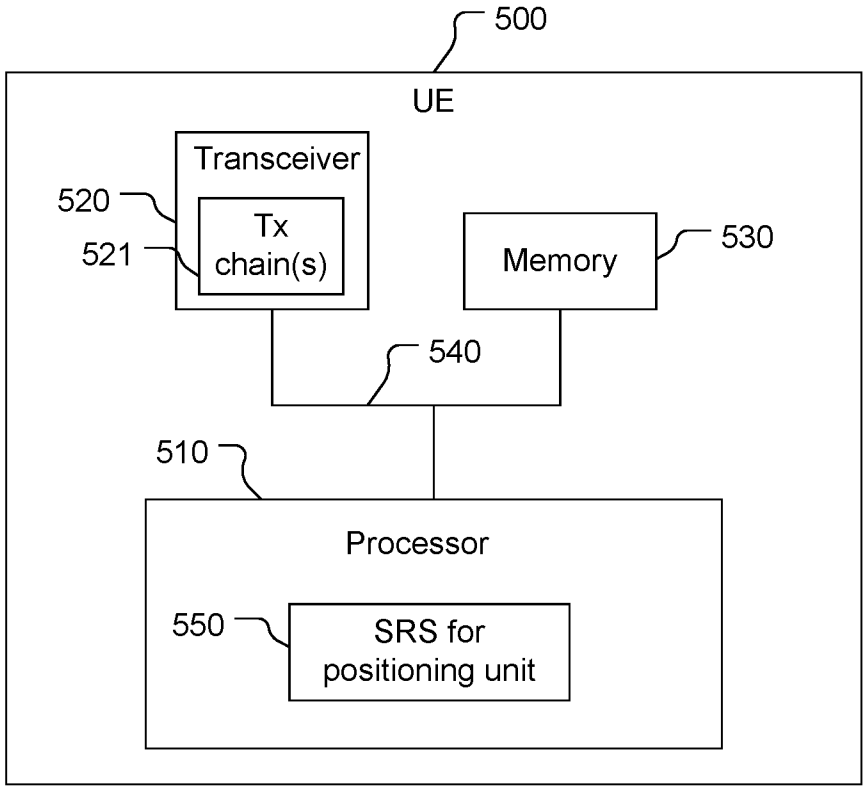

500
UE
Transceiver
520
Tx
chain(s)
521
Memory
530
540
510
Processor
550
SRS for
positioning unit

FIG. 5

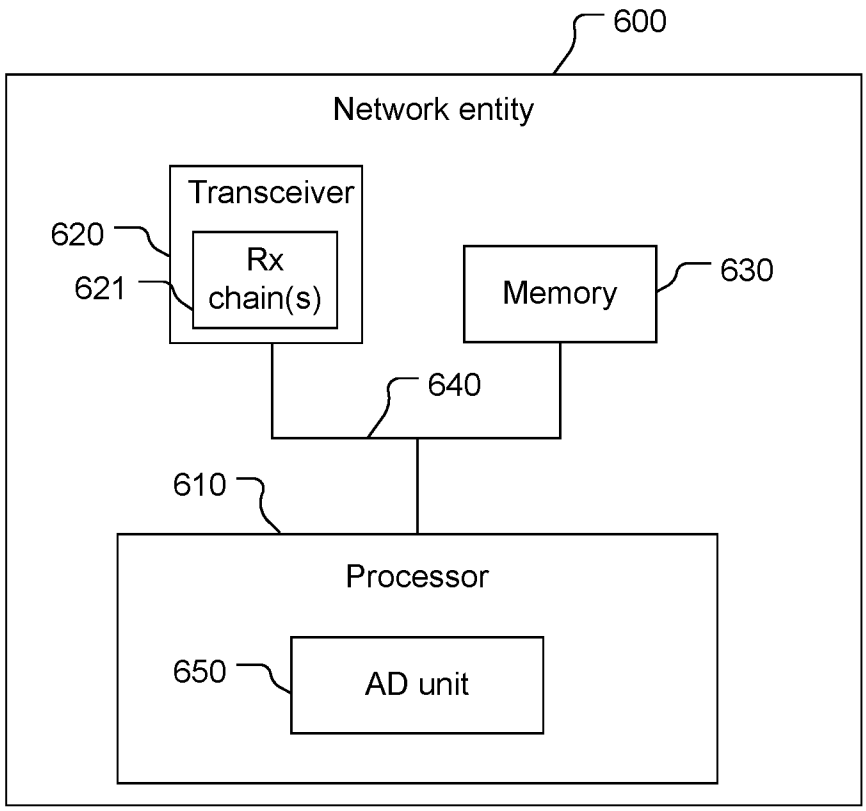

600
Network entity
Transceiver
620
Rx
chain(s)
621
Memory
630
640
610
Processor
650
AD unit

FIG. 6

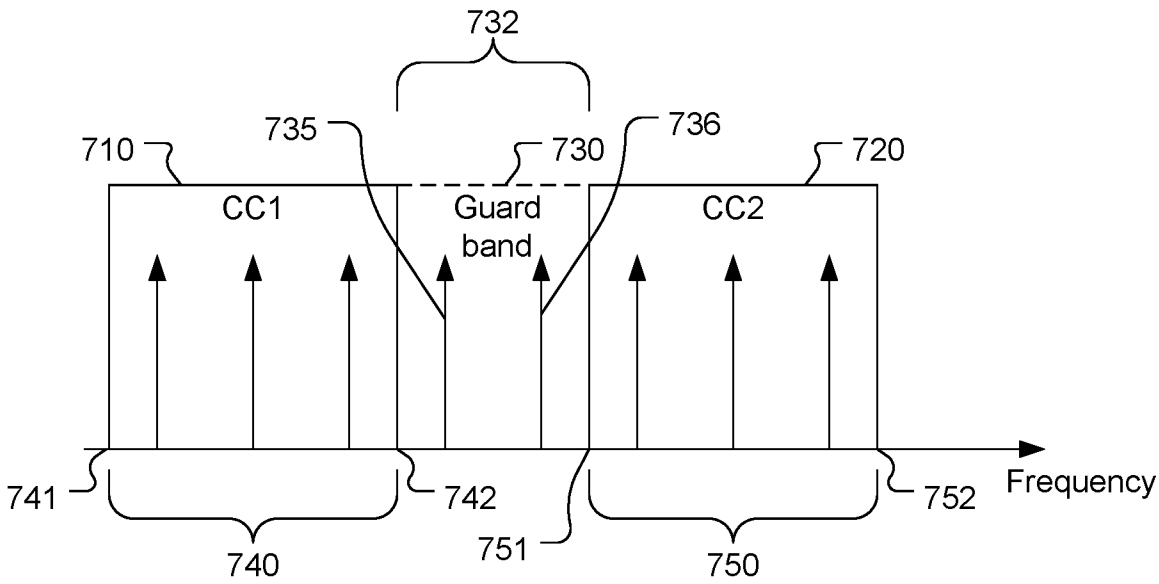

732
735
736
710
730
720
CC1
Guard band
CC2
741
742
752
Frequency
740
751
750

FIG. 7

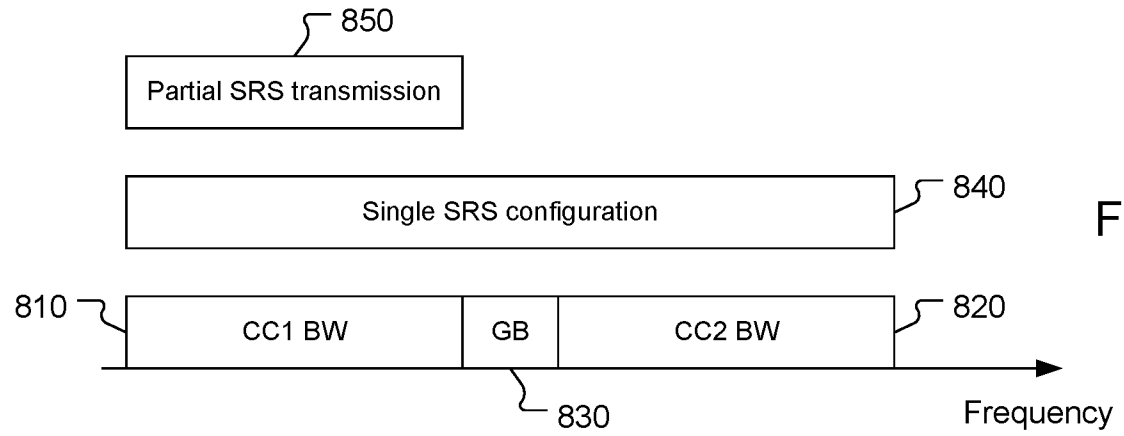


FIG. 8

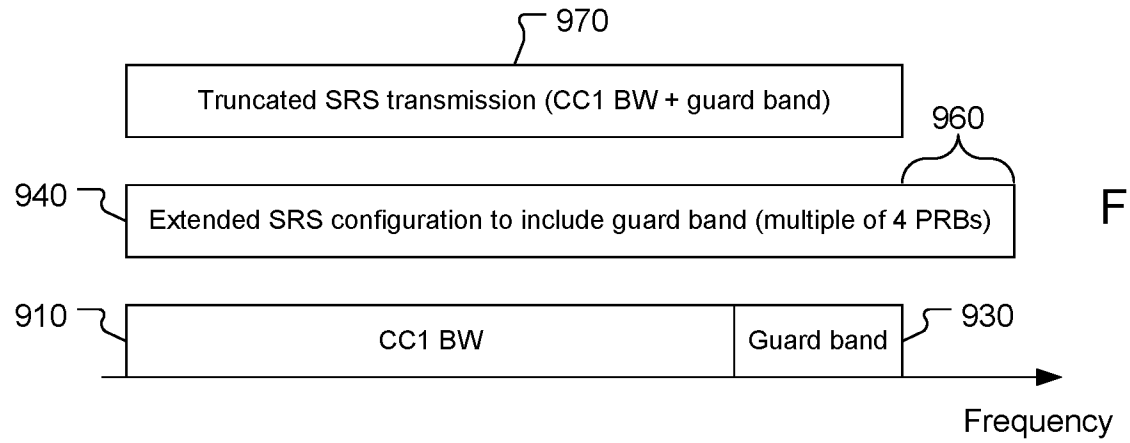


FIG. 9

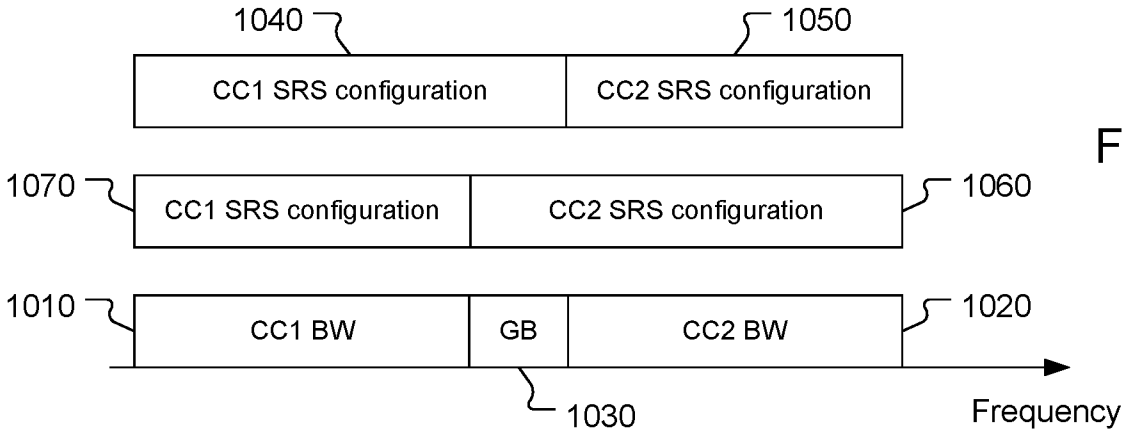


FIG. 10

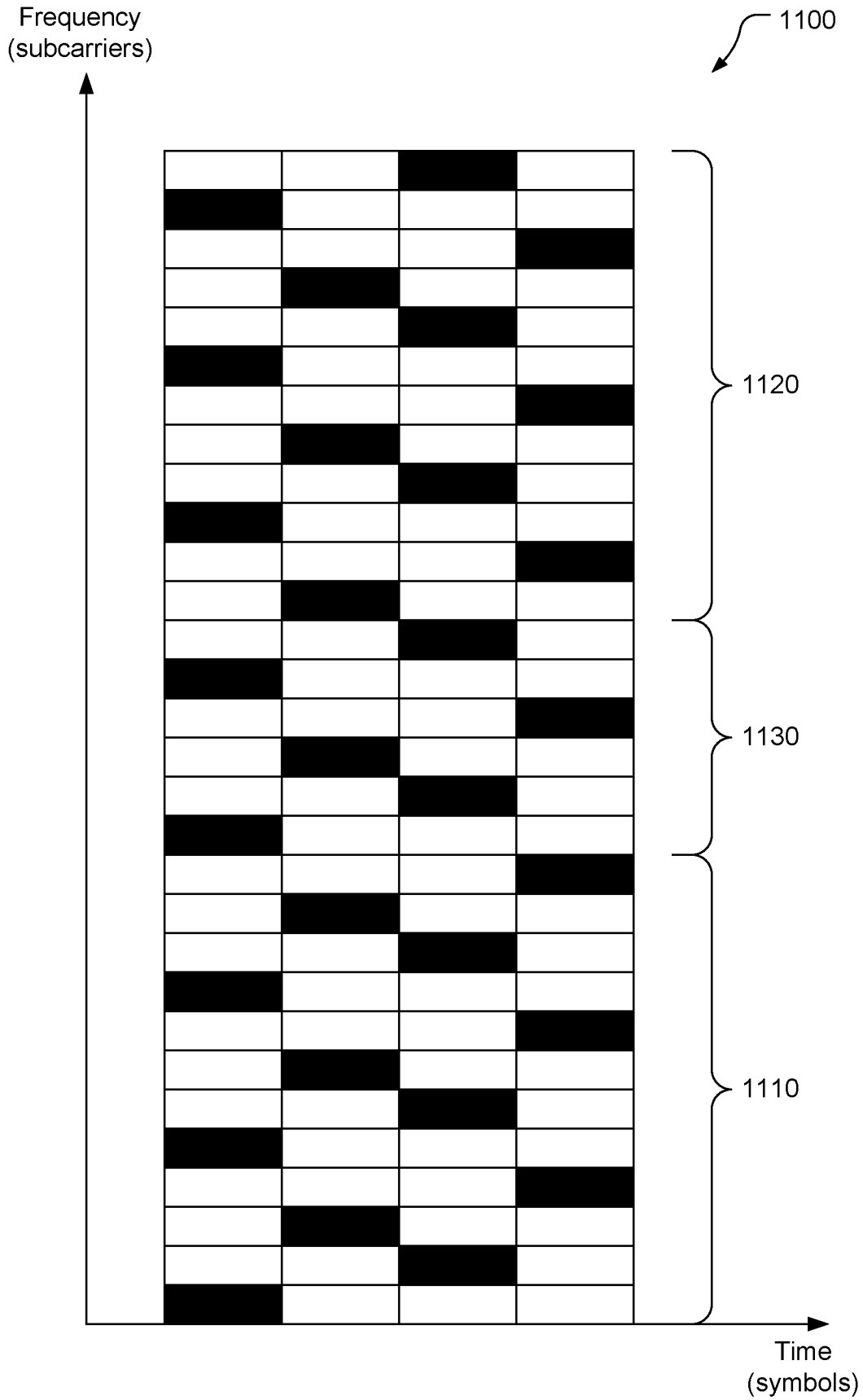


FIG. 11

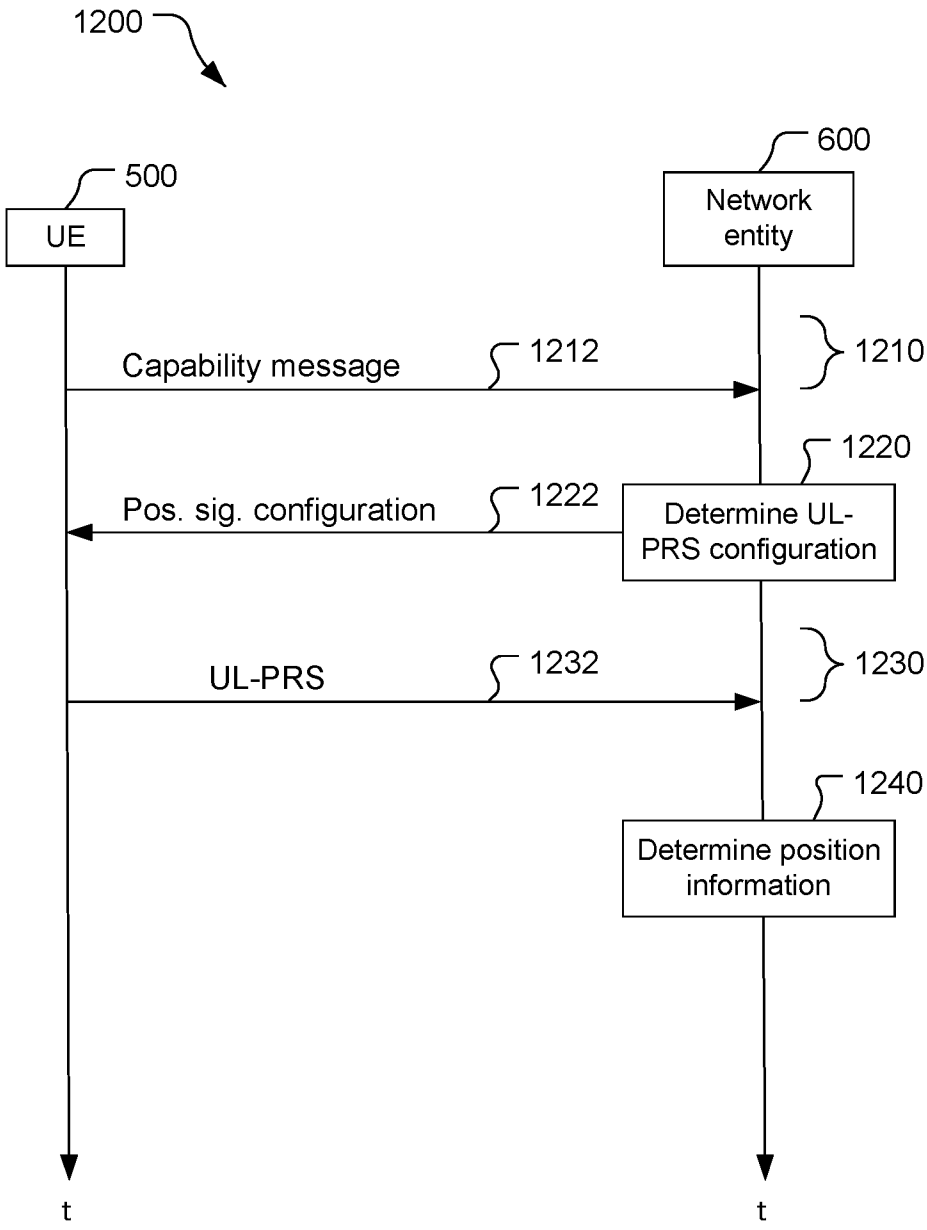

1200
600
500
Network entity
UE
1210
Capability message
1212
1220
Pos. sig. configuration
1222
Determine UL-PRS configuration
1230
UL-PRS
1232
1240
Determine position information
t
t

FIG. 12

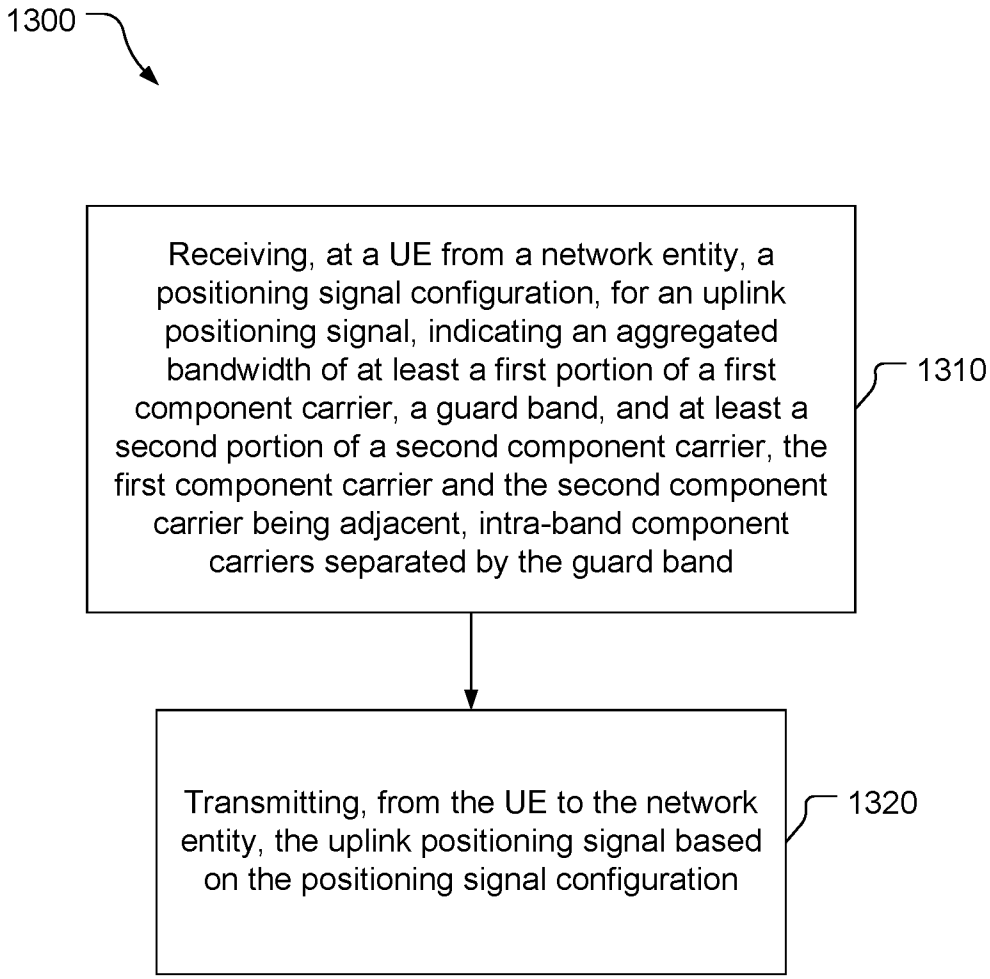

1300
Receiving, at a UE from a network entity, a positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band
1310
Transmitting, from the UE to the network entity, the uplink positioning signal based on the positioning signal configuration
1320

FIG. 13

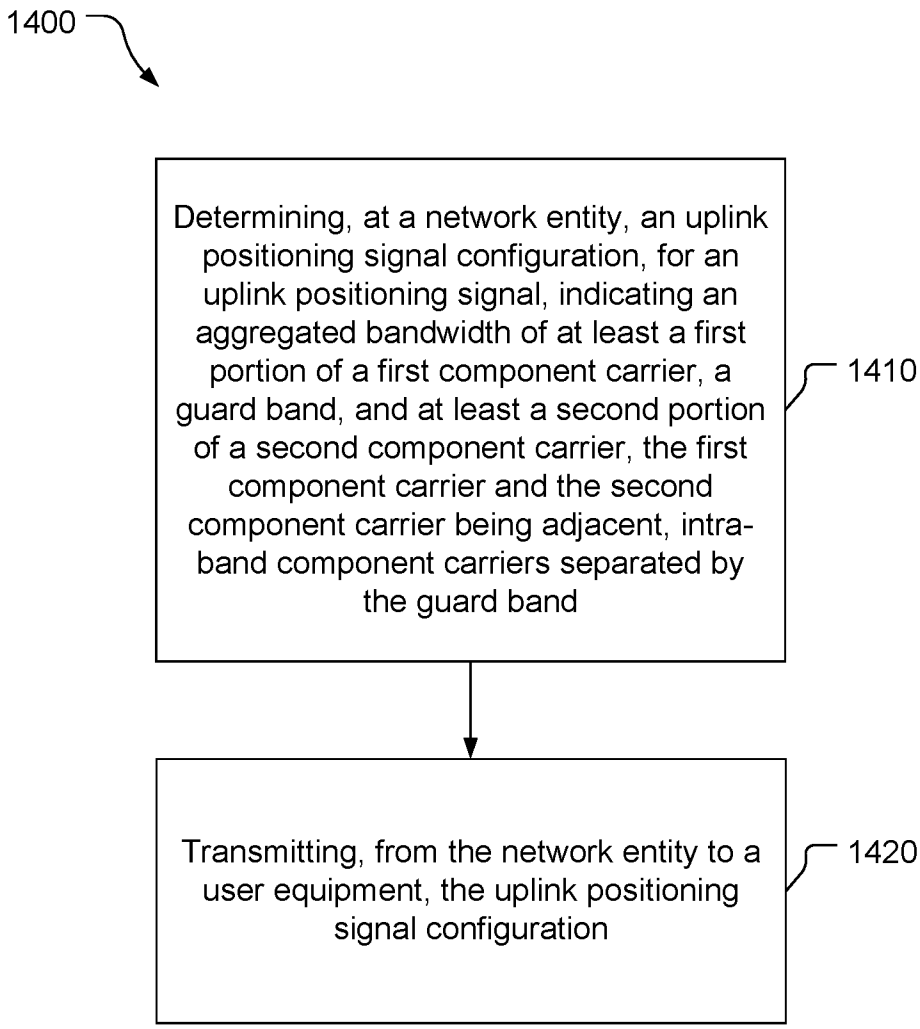

1400
Determining, at a network entity, an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band
1410
Transmitting, from the network entity to a user equipment, the uplink positioning signal configuration
1420

FIG. 14

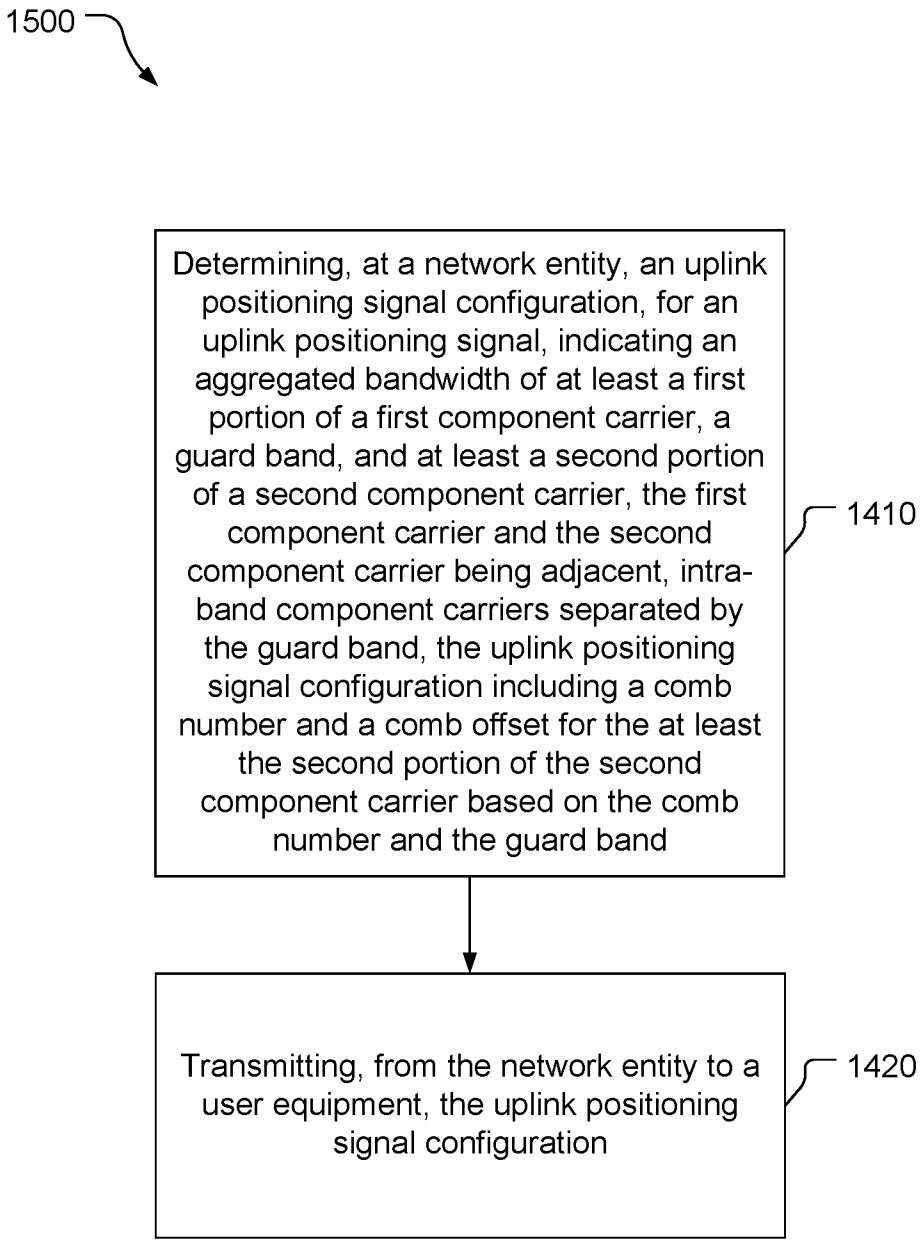

1500
Determining, at a network entity, an uplink positioning signal configuration, for an uplink positioning signal, indicating an aggregated bandwidth of at least a first portion of a first component carrier, a guard band, and at least a second portion of a second component carrier, the first component carrier and the second component carrier being adjacent, intra-band component carriers separated by the guard band, the uplink positioning signal configuration including a comb number and a comb offset for the at least the second portion of the second component carrier based on the comb number and the guard band
1410
Transmitting, from the network entity to a user equipment, the uplink positioning signal configuration
1420

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/080458

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L27/26 H04L5/00 H04W64/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L H04W

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2020/351047 A1 (AKKARAKARAN SONY [US] ET AL) 5 November 2020 (2020-11-05)	1-4, 6-12, 14-20, 22-28,30
A	paragraph [0187] paragraph [0039]	5,13,21, 29
A	WO 2022/135477 A1 (VIVO MOBILE COMMUNICATION CO LTD [CN]) 30 June 2022 (2022-06-30) paragraph [0029] - paragraph [0030] paragraph [0066] paragraph [0070] - paragraph [0071]	1-30

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 March 2024	14/03/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Douglas, Ian

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2023/080458

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020351047 A1	05-11-2020	CN 113711656 A	26-11-2021
		EP 3963973 A1	09-03-2022
		KR 20220004040 A	11-01-2022
		TW 202102017 A	01-01-2021
		US 2020351047 A1	05-11-2020
		US 2022006586 A1	06-01-2022
		WO 2020223307 A1	05-11-2020
WO 2022135477 A1	30-06-2022	CN 114666890 A	24-06-2022
		WO 2022135477 A1	30-06-2022