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

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

(43) **International Publication Date**
05 December 2024 (05.12.2024)

WIPO | PCT

(10) **International Publication Number**
WO 2024/249586 A1

(51) **International Patent Classification:**
G01S 5/02 (2010.01) *G01S 11/10* (2006.01)

(21) **International Application Number:**
PCT/US2024/031599

(22) **International Filing Date:**
30 May 2024 (30.05.2024)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
23176918.3 02 June 2023 (02.06.2023) EP

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

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

(54) **Title:** METHODS, ARCHITECTURES, APPARATUSES AND SYSTEMS FOR ENHANCED POSITIONING IN LINE OF SIGHT AND NON-LINE OF SIGHT CONDITIONS

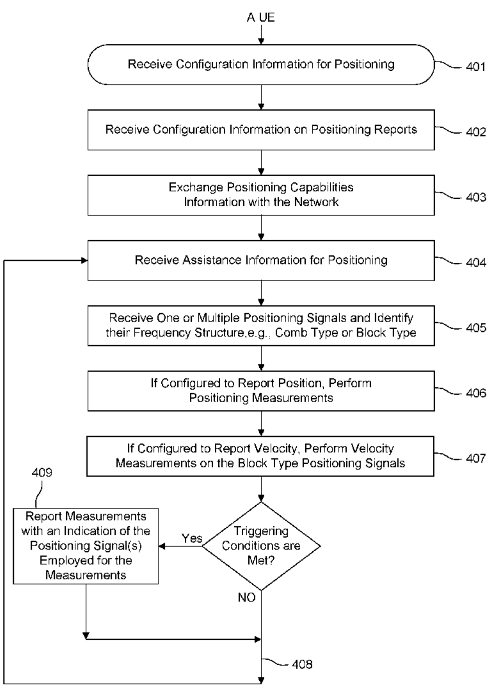

FIG. 4

(57) **Abstract:** Procedures, methods, architectures, apparatuses, systems, devices, and computer program products implemented by a wireless transmit/receive unit (WTRU), the method comprising receiving, from a network node, configuration information to perform positioning measurements of the WTRU; receiving, from the network node, one or more positioning signals; performing positioning measurements over the one or more positioning signals based on the configuration information; and determining a location uncertainty of the WTRU based on the positioning measurements.

WO 2024/249586 A1

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Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

METHODS, ARCHITECTURES, APPARATUSES AND SYSTEMS FOR ENHANCED POSITIONING IN LINE OF SIGHT AND NON-LINE OF SIGHT CONDITIONS

FIELD

[0001] The present disclosure is generally directed to the fields of communications, software and encoding, including, for example, to methods, architectures, apparatuses, systems related to positioning methods and procedures in wireless cellular communications.

SUMMARY

[0002] There is disclosed methods and procedures to enhance the loss in positioning accuracy of target WTRUs (e.g., UEs) that are in Non-Line of Sight (NLOS) conditions, by means of measurements performed over a multiplicity of positioning signals with different frequency structures (e.g., comb and block types) at either Line of Sight (LOS) or NLOS. “Block type positioning signals” are denoted as those having contiguously allocated subcarriers in at least one frequency portion, and allow velocity measurements in addition to positioning. Velocity can be used by the WTRU (e.g., UE) and/or the network to refine the WTRU (e.g., UE) coordinates and its location uncertainty.

[0003] The WTRU (e.g., UE) is configured to perform measurements on one or multiple positioning reference signals and report them according to some triggering conditions. The WTRU (e.g., UE) performs positioning measurements and, if it detects one or more block-type positioning signals, it performs velocity estimation according to the WTRU (e.g., UE) positioning capabilities. Velocity estimation can be derived from, e.g., the sum of certain subcarrier values of the spectrum of the instantaneous frequency signal obtained after concatenating the symbols and removing any known signal values. Velocity estimates can be used by the WTRU (e.g., UE) to refine its coordinates and the location uncertainty.

[0004] WTRU (e.g., UE) measurements of position, velocity, and location uncertainty are reported by the WTRU (e.g., UE) in a positioning report that is transmitted back to the network in a periodic, aperiodic or semi-persistent fashion according to the triggering conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A more detailed understanding may be had from the detailed description below, given by way of example in conjunction with drawings appended hereto. Figures in such drawings, like the detailed description, are examples. As such, the Figures (FIGs.) and the detailed description are not to be considered limiting, and other equally effective examples are possible and likely. Furthermore, like reference numerals ("ref.") in the FIGs. indicate like elements, and wherein:

[0006] FIG. 1A is a system diagram illustrating an example communications system;

[0007] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A;

[0008] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A;

[0009] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A;

[0010] FIG. 2 is a system diagram illustrating time of arrival of wireless signals of a communications system;

[0011] FIG. 3 is a system diagram illustrating the time difference of arrival between wireless signals of a communications system;

[0012] FIG. 4 is a system diagram illustrating a procedure for enhanced positioning in LOS and NLOS;

[0013] FIG. 5 is a system diagram illustrating a procedure for WTRU (E.G., UE) tracking in LOS and NLOS;

[0014] FIG. 6 illustrates a power spectrum of the random FM noise in Rayleigh channel;

[0015] FIG. 7 illustrates a concatenation of the symbols in a slot containing block reference signals to yield a velocity resolution determined by the length of a Discrete Fourier Transform (DFT) window;

[0016] FIG. 8 is a system diagram illustrating refinement of the WTRU (E.G., UE) location uncertainty at time instant n based on velocity and the past WTRU (E.G., UE) location at time instant n-1;

[0017] FIG. 9 is a system diagram illustrating the interplay between two positioning signals aimed for positioning and velocity estimation in LOS and NLOS links along a WTRU (E.G., UE) trajectory;

[0018] FIG. 10 is a flowchart illustrating an example of a method to enhance the loss in positioning accuracy of a WTRU; and

[0019] FIG. 11 is another flowchart illustrating an example of a method to enhance the loss in positioning accuracy of a WTRU.

DETAILED DESCRIPTION

[0020] In the following detailed description, numerous specific details are set forth to provide a thorough understanding of embodiments and/or examples disclosed herein. However, it will be understood that such embodiments and examples may be practiced without some or all of the specific details set forth herein. In other instances, well-known methods, procedures, components and circuits have not been described in detail, so as not to obscure the following description. Further, embodiments and examples not specifically described herein may be practiced in lieu of, or in combination with, the embodiments and other examples described, disclosed or otherwise provided explicitly, implicitly and/or inherently (collectively "provided") herein. Although various embodiments are described and/or claimed herein in which an apparatus, system, device, etc. and/or any element thereof carries out an operation, process, algorithm, function, etc. and/or any portion thereof, it is to be understood that any embodiments described and/or claimed herein assume that any apparatus, system, device, etc. and/or any element thereof is configured to carry out any operation, process, algorithm, function, etc. and/or any portion thereof.

[0021] Example Communications System

[0022] The methods, apparatuses and systems provided herein are well-suited for communications involving both wired and wireless networks. An overview of various types of wireless devices and infrastructure is provided with respect to FIGs. 1A-1D, where various elements of the network may utilize, perform, be arranged in accordance with and/or be adapted and/or configured for the methods, apparatuses and systems provided herein.

[0023] FIG. 1A is a system diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail (ZT) unique-word (UW) discreet Fourier transform (DFT) spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0024] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104/113, a core network (CN) 106/115, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a "station" and/or a "STA", may be configured to transmit and/or receive wireless signals and may include (or be) a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0025] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d, e.g., to facilitate access to one or more communication networks, such as the CN 106/115, the Internet 110, and/or the networks 112. By way of example, the base stations 114a, 114b may be any of a base transceiver station (BTS), a Node-B (NB), an eNode-B (eNB), a Home Node-B (HNB), a Home eNode-B (HeNB), a gNode-B (gNB), a NR Node-B (NR NB), a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0026] The base station 114a may be part of the RAN 104/113, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in an embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each or any sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0027] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0028] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104/113 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0029] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0030] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using New Radio (NR).

[0031] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0032] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (Wi-Fi), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0033] The base station 114b in FIG. 1A may be a wireless router, Home Node-B, Home eNode-B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR, etc.) to establish any of a small cell, picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106/115.

[0034] The RAN 104/113 may be in communication with the CN 106/115, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106/115 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing an NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing any of a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or Wi-Fi radio technology.

[0035] The CN 106/115 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104/114 or a different RAT.

[0036] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0037] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other elements/peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0038] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together, e.g., in an electronic package or chip.

[0039] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in an embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In an embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0040] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. For example, the WTRU 102 may employ MIMO technology. Thus, in an embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0041] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0042] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0043] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0044] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0045] The processor 118 may further be coupled to other elements/peripherals 138, which may include one or more software and/or hardware modules/units that provide additional features, functionality and/or wired or wireless connectivity. For example, the elements/peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (e.g., for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a virtual reality and/or augmented reality (VR/AR) device, an activity tracker, and the like. The elements/peripherals 138 may include one or more sensors, the sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor; an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, and/or a humidity sensor.

[0046] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the uplink (e.g., for transmission) and downlink (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the uplink (e.g., for transmission) or the downlink (e.g., for reception)).

[0047] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, and 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0048] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In an embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a.

[0049] Each of the eNode-Bs 160a, 160b, and 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink (UL) and/or downlink (DL), and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0050] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While each of the foregoing elements are depicted as part of the CN 106, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the CN operator.

[0051] The MME 162 may be connected to each of the eNode-Bs 160a, 160b, and 160c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0052] The SGW 164 may be connected to each of the eNode-Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode-B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0053] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0054] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0055] Although the WTRU is described in FIGs. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0056] In representative embodiments, the other network 112 may be a WLAN.

[0057] A WLAN in infrastructure basic service set (BSS) mode may have an access point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have an access or an interface to a distribution system (DS) or another type of wired/wireless network that carries traffic into and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an "ad-hoc" mode of communication.

[0058] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier sense multiple access with collision avoidance (CSMA/CA) may be implemented, for example in in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0059] High throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0060] Very high throughput (VHT) STAs may support 20 MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse fast fourier transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above-described operation for the 80+80 configuration may be reversed, and the combined data may be sent to a medium access control (MAC) layer, entity, etc.

[0061] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV white space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support meter type control/machine-type communications (MTC), such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0062] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or network allocation vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode), transmitting to the AP, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0063] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0064] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0065] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In an embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the WTRUs 102a, 102b, 102c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0066] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., including a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0067] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0068] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards user plane functions (UPFs) 184a, 184b, routing of control plane information towards access and mobility management functions (AMFs) 182a, 182b, and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0069] The CN 115 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one session management function (SMF) 183a, 183b, and at least one Data Network (DN) 185a, 185b. While each of the foregoing elements are depicted as part of the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0070] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b, e.g., to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and/or the like. The AMF 162 may provide a control plane function for switching between the RAN 113 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as Wi-Fi.

[0071] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0072] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, e.g., to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering downlink packets, providing mobility anchoring, and the like.

[0073] The CN 115 may facilitate communications with other networks. For example, the CN 115 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem

(IMS) server) that serves as an interface between the CN 115 and the PSTN 108. In addition, the CN 115 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In an embodiment, the WTRUs 102a, 102b, 102c may be connected to a local Data Network (DN) 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0074] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 1A-1D, one or more, or all, of the functions described herein with regard to any of: WTRUs 102a-d, base stations 114a-b, eNode-Bs 160a-c, MME 162, SGW 164, PGW 166, gNBs 180a-c, AMFs 182a-b, UPFs 184a-b, SMFs 183a-b, DNs 185a-b, and/or any other element(s)/device(s) described herein, may be performed by one or more emulation elements/devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0075] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or may performing testing using over-the-air wireless communications.

[0076] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0077] Introduction

[0078] In the following description: “Reference signals for positioning” and “positioning signals” may be interchangeably used. A “comb reference signal”, “comb type reference signal”, or “comb signal” may refer to a signal with a comb-like frequency structure that allows to frequency-multiplex different signals from TRPs or UEs without interference, over one or multiple symbols. The terms “block reference signal”, “block type reference signal”, “block signal”, or “positioning signal with a block frequency structure” may refer to any reference signal having contiguously allocated subcarriers in at least one specified frequency region, and one or multiple time-domain symbols. DL allocation to different TRPs, or UL allocation to multiple WTRU (e.g., UEs), may be done over non-overlapping RBs to avoid interference. “UE” and “WTRU” may be used interchangeably as synonyms of a user device. “BS” and “TRP” are synonyms of a base station. “LMF” is a non-limiting example of a node or entity (e.g., network node or entity) that may be used for or to support positioning. Any other node or entity may be substituted for LMF and still be consistent with this disclosure. For easier understanding, references are sometimes made in relation to DL Positioning Reference Signals (DL PRS) and/or UL Sounding Reference Signals for Positioning (UL SRSp) signals, but they can be straightforwardly applied to any other signals by following the same convention.

[0079] Methods and apparatus for Enhanced positioning in LOS and NLOS conditions are provided. In one embodiment, the WTRU (e.g., UE) may be configured to perform positioning measurements over one or multiple positioning signals.

[0080] Positioning signals can be, e.g., of comb or block type: (1) comb-type for positioning in LOS, and/or (2) block-type for positioning and velocity estimation in NLOS.

[0081] Measurements can be: (1) Quantities related with positioning can be, e.g., Reference Signal Time Difference (RSTD), Round-Trip Time (RTT), Angle of Arrival (AoA), Angle of Departure (AoD), beam id, estimated WTRU (e.g., UE) coordinates, etc.; and/or (2) quantities related with velocity can be, e.g., the averaged instantaneous frequency spectrum, estimated WTRU (e.g., UE) velocity, measurement bandwidth (BW), etc.

[0082] The WTRU (e.g., UE) may receive one or multiple positioning signals and may identify their frequency structure based on either: time and frequency configuration of each signal type; or blind or semi-blind detection

[0083] If the WTRU (e.g., UE) is configured to report positioning, it may perform positioning measurements and obtains its location uncertainty.

[0084] If the WTRU (e.g., UE) is configured to report velocity measurements in addition to positioning and it detects one or more positioning signals with block frequency structure, it may leverage them to measure any of: (1) velocity, e.g., from the DFT of the instantaneous frequency signal after removing the known phases; (2) refined WTRU (e.g., UE) coordinates and location uncertainty, based on, e.g., the velocity estimate and current or past positioning estimations; (3) the measurement BW for velocity can be restricted to the channel’s coherence BW, if smaller than the signal BW.

[0085] If triggering conditions are met, the WTRU (e.g., UE) may send a positioning report back to the network via, e.g., UCI, MAC-CE, PUSCH, PUCCH, etc. containing positioning-related and velocity-related measurements.

[0086] Triggering conditions can be, e.g.: (1) #LOS links above T1 and velocity above T2: position+velocity; (2) #LOS links above T1 and velocity below T2: position; (3) #LOS links below T1: position+velocity; (4) a network request.

[0087] Reports can be periodical, semi-periodical or aperiodic.

[0088] Reports may include the positioning signals employed for the measurements (e.g., using a flag, sequence identifier, time stamp of reception, etc.), the actual quantities being reported (e.g., with a bit field or a special indicator), and the measurement BW used for velocity estimations.

[0089] The WTRU (e.g., UE) may stop reporting if triggering conditions are not met, or upon network request, or the WTRU (e.g., UE) no longer receives at least one positioning signal.

[0090] Methods and apparatus for WTRU (e.g., UE) tracking in LOS and NLOS conditions are provided.

[0091] In one embodiment, a network node (e.g., Location Management Function (LMF)) may select the number of Transmit-Receive Points (TRPs) involved in the trajectory estimation of a moving WTRU (e.g., UE) based on, e.g., their LOS/NLOS likelihood, signal to noise ratios, user velocities, etc.

[0092] The network node (e.g., LMF) may construct one or multiple reference signals for positioning based on, e.g., the LOS/NLOS likelihood, velocity, or the positioning resources consumption, wherein at least one signal is of block type to enable NLOS velocity estimation and at least one signal is of comb type to enable accurate LOS positioning.

[0093] The network node (e.g., LMF) may select the time intervals for transmission of the one or multiple positioning signals based on, e.g., velocity, expected covered distance, or geographic information.

[0094] The network (e.g., the set of TRPs) may transmit and/or receive one or multiple reference signals for positioning.

[0095] The network node (e.g., LMF) may obtain reports containing positioning measurements (e.g., coordinates, velocity, and location uncertainty) from the UE.

[0096] The network node (e.g., LMF) may refine the WTRU (e.g., UE) coordinates based on velocity and the current or past positioning estimations and may adjust the BW of the block positioning signals based on the reported values of the measurement BW used by the WTRU (e.g., UEs).

[0097] The proposed enhanced positioning methods may leverage the use of one or multiple positioning signals with possibly different signal structures for LOS and NLOS conditions, e.g. (but not limited to), the comb-type or block-type signals.

[0098] **Techniques for cellular positioning**

[0099] Some of the state-of-the-art categories of cellular positioning techniques include range-based techniques. These are based on the timing information corresponding to, at least, three TRPs that jointly cooperate for positioning. As illustrated in **FIG. 2**, the time of arrival (ToA) of the wireless signals received from, or transmitted to, at least TRPs defines three geometric circles whose intersection marks the estimated WTRU (e.g., UE) location. As illustrated in **FIG. 3**, the time difference of arrival (TdoA) between the signals corresponding to two different pairs of TRPs defines two hyperbolas whose intersection marks the estimated WTRU (e.g., UE) location. TdoA techniques for the downlink are sometimes called observed time difference of arrival (OTDoA), as opposed to TDoA techniques for the uplink that are sometimes called uplink time difference of Arrival (UTDoA). In some cases, time measurements can be performed in the frequency domain by estimating the linear progressive phase in the positioning signals between any two consecutive resource elements (REs), assuming that their channel responses are similar (i.e., the channel's coherence bandwidth is higher than the frequency separation between REs).

[0100] According to certain embodiments round-trip time (RTT) measurements may be exploited based on both the TRP and the WTRU (e.g., UE) transmitting positioning signals in a consecutive way, to infer the WTRU (e.g., UE) position while avoiding the TRP-UE clock synchronization error issues.

[0101] Other angular-based positioning techniques rely on estimation of the downlink angle of departure (DL-AoD), or uplink angle of arrival (UL-AoA), of the positioning signals corresponding to two or more TRPs that help define intersection areas where the WTRU (e.g., UE) is located.

[0102] Some systems, like NR, may employ a combination of the above techniques, e.g., OTDoA and DL-AoD, or UTDoA and UL-AoA, depending on the service requirements. Measurements may be fused together either at the UE, TRP, or the network (e.g., the Location Management Function, LMF) to estimate the position of the target WTRU (e.g., UE) in terms of either 2D or 3D coordinates.

[0103] Trajectories of moving devices may be estimated by continuously updating the user positions estimated via GNSS or cellular techniques. When small cells are used, an approximate trajectory may also be estimated by updating the time evolution of the active cells throughout the connection. In other systems, trajectories may be estimated by additionally obtaining the Doppler shift that appears in the received signals because of mobility, which may give an indication of the user's velocity in a LOS scenario.

[0104] Positioning Reference Signals

[0105] 3GPP New Radio (NR) specifications in Release 16 define DL Positioning Reference Signals (DL PRS) and UL Sounding Reference Signals for Positioning (UL SRSp), enabling a positioning accuracy of less than 3 m (indoor) and less than 10 m (outdoor) in general commercial use cases. The higher requirements set by new industry verticals, with less than 1 m for commercial use cases and less than 0.2 m for Industrial Internet of Things (IioT) use cases, were addressed in Release 17, as well as other enhancements like lower positioning latency, on-demand PRS, or GNSS support, among others. Several other enhancements are also in discussion, like the use of carrier phase positioning to improve the accuracy.

[0106] DL PRS signal is a one-port signal spanning up to 272 RBs in frequency and up to 12 OFDM symbols per slot in time, with a comb, frequency-staggered arrangement to allow for signal multiplexing from multiple TRPs without collisions. DL PRS resources are grouped into PRS resource sets, wherein PRS resources belonging to one PRS resource set can employ a different spatial filter for beamforming. PRS resource sets can be time-multiplexed across different symbols or slots, e.g., to allow for different spatial filters in beamformed PRS. PRS can be quasi co-located (QCL)-type D with other DL reference signals, i.e., the receive spatial filter employed to detect PRS can be assumed to be equal to that of the DL reference signal. PRS resource sets can be repeated for improved coverage, thereby allowing a measurement gap period to be defined between repetitions, and/or muted to avoid interferences to/from other cells. PRS signals can also be aperiodic with no measurement gap, to reduce latency, and can be initiated by WTRU (e.g., UEs) in an on-demand fashion.

[0107] UL SRS signal for positioning (UL SRSp) is a one-port signal spanning up to 14 consecutive OFDM symbols in a slot and up to full bandwidth in a frequency-staggered fashion, to allow for signal multiplexing from multiple users without collisions. It shares many of the properties of the DL PRS signals.

[0108] PRS and SRSp signals employ sequences with good auto-correlation properties so that the receiver can easily obtain the relative timing information through correlations with cyclically shifted sequence replicas. In some cases, OTDoA positioning techniques may employ NR DL PRS signals for positioning. In other cases, UTDoA techniques may employ NR UL SRS signals for positioning. Receivers in both cases extract the relative timing between the PRS or SRS signals corresponding to different TRPs. TRPs may be time-synchronized to follow a common time reference and ease the task of deriving positioning, but in some cases may also be non-synchronized.

[0109] Further enhancements to 3GPP NR DL PRS and UL SRSp are proposed comprising different types of positioning signals, namely comb-type (applicable to LOS conditions) and block-type (applicable to NLOS conditions). The block structure of the latter ones facilitates velocity estimations in absence of line-of-sight conditions by measuring the instantaneous frequency spectrum averaged across all the positioning TRPs.

[0110] Overview

[0111] 3GPP Rel-16 and Rel-17 for NR supports cellular-based OTDoA and UTDoA ranging positioning techniques, and other angular positioning methods based on, e.g., estimation of the Angle of Departure (AoD) and/or Angle of Arrival (AoA), based on positioning reference signals.

[0112] Further alternatives to NR positioning signals were proposed to enable positioning and velocity estimation in NLOS conditions.

[0113] Cellular-based positioning techniques like OTDoA and UTDoA, and those based on AoD/AoA, suffer from significant inaccuracies in NLOS scenarios because of the timing or angular errors introduced by the multipath components. This situation may often be encountered in cellular urban channels. State-of-the-art techniques involve procedures to detect the likelihood of NLOS to further exclude those measurements when appropriate. However, they may be imprecise and pose significant resources consumption from the unused positioning Resource Elements (REs). To compensate for this, the system may involve additional TRPs to maximize the likelihood of being in LOS for at least three of them, but this may lead again to very high resources consumption and require additional signalling.

[0114] For example, a WTRU (e.g., UE) may encounter a significant number of TRP-UE links in NLOS conditions that may lead to poor positioning accuracy.

[0115] For example, a network may discard the measurements from NLOS links if deemed contributing to poor positioning accuracy, thereby leading to waste of positioning resources assigned to the corresponding TRPs.

[0116] It would be desirable to extract additional intermediary metrics, like velocity, to assist with improving the WTRU (e.g., UE) location accuracy and minimize waste of unused resources in NLOS conditions. Techniques for velocity estimation based on Doppler shift are not valid in NLOS as the appearance of a Doppler spread renders Doppler shift measurements generally useless.

[0117] Velocity measurements may be beneficial in addition to positioning measurements, e.g., to narrow down the location uncertainty based on the current and past positioning estimates, to better adjust the rate of positioning signals needed for a moving device, and to further prepare anticipatory actions in RRM events like, e.g., beam tracking, handover prediction, beam failure recovery, minimization of radio link failures, etc.

[0118] Communication is assumed to be established between one or multiple devices (also known as User Equipment, UEs, or Wireless Transmit-Receive Units, WTRUs) and one or multiple base stations (BSs) that provide means for connection to the network. In some cases, the term Transmission-Reception Point (TRP) is used instead of BS, particularly in multi-TRP scenarios where more than one TRP can collaborate in the transmission/reception of signals to/from users.

[0119] A cellular scenario may be considered where a network comprising several TRPs establishes wireless connections to one or multiple moving WTRU (e.g., UEs). The links between the TRPs and the one or multiple WTRU (e.g., UEs) may exhibit LOS and/or NLOS conditions.

[0120] Solutions described hereinafter are applicable, without loss of generality, to any signal waveform susceptible of frequency-domain analysis by means of DFTs. For simplicity, an OFDM-like waveform, like CP-OFDM or DFT-s-OFDM, will be used in the descriptions with N discrete samples in the time or frequency domain.

[0121] Enhanced positioning in LOS and NLOS conditions

[0122] In an exemplary embodiment exemplified in **FIG. 4**, a WTRU (e.g., UE) or set of WTRU (e.g., UEs) receiving signals from the network for positioning may perform any of the following steps:

[0123] In a step 401, the WTRU (e.g., UE) may receive configuration information for positioning from the network with a multiplicity of positioning signals (e.g., PRS resource IDs, time, frequency information, etc.).

[0124] In a step 402, the WTRU (e.g., UE) may receive configuration information on the reports to send (e.g., triggering conditions, repetition information, measurements to report, etc.).

[0125] In a step 403, the WTRU (e.g., UE) may exchange positioning capabilities information with the network (e.g., on the support of one or multiple reference signals for positioning, maximum / minimum supported velocities, etc.).

[0126] In a step 404, the WTRU (e.g., UE) may receive assistance information for positioning (e.g., spatial characteristics of the positioning beams, TRP coordinates, LOS/NLOS indications, etc.).

[0127] In a step 405, the WTRU (e.g., UE) may receive the one or multiple reference signals for positioning and identifies their frequency structure (e.g., comb type or block type), based on, e.g., the frequency configuration, time configuration, blind detection, etc.

[0128] In a step 406, if the WTRU (e.g., UE) is configured to report positioning, it may perform positioning measurements on the one or multiple positioning signals (e.g., RSTD, RTT, RSRP, beam id, AoD, AoD, etc.) and obtains its location uncertainty.

[0129] In a step 407, if the WTRU (e.g., UE) is configured to report velocity and it detects at least one positioning signal with a block frequency structure, the WTRU (e.g., UE) may measure velocity on the one or multiple block positioning signals based on, e.g., the instantaneous frequency spectrum. The WTRU (e.g., UE) may obtain refined values of the WTRU (e.g., UE) coordinates and location uncertainty based on, e.g., the velocity estimate and current or past positioning estimations.

[0130] In a step 408, if triggering conditions are met (e.g., velocity above a threshold, number of LOS links below or above a threshold, a network request, etc.), the WTRU (e.g., UE) may report measurements and/or the positioning signals employed for each measurement via UL control signaling, e.g., UCI, MAC-CE, PUSCH, PUCCH, etc.

[0131] Measurements can be, e.g., positioning measurements, velocity measurements, coordinates before and after refinement with velocity, location uncertainty before and after refinement with velocity, etc.

[0132] Positioning signals employed for the measurements can be indicated, e.g., using a flag, sequence identifier, time stamp of reception (e.g., the symbol index, slot index, frame index, etc. in absolute or relative terms), etc.

[0133] Actual reported quantities can be signaled, e.g., with a bit field or an explicit indication, or the WTRU (e.g., UE) may signal the absence of any quantity in the report by means of a pre-defined value in the corresponding field.

[0134] Periodicity of the reports may be given by the repetition information in the configuration phase (e.g., aperiodic, semi-persistent or periodic reporting, with a configured periodicity).

[0135] In a step 408, the WTRU (e.g., UE) may determine to stop the reporting based on certain conditions, e.g., if triggering conditions are not met, or upon network request, or the WTRU (e.g., UE) no longer receives at least one positioning signal.

[0136] According to certain embodiments, the parameters of the reference signals for positioning may include, e.g., the resource ID(s) and resource set ID(s), time configurations, frequency configurations, repetition configurations, triggering conditions for reporting, repetition information for reporting, and quantities to report.

[0137] According to certain embodiments, the positioning configuration, positioning reports configuration, and assistance information for positioning may be received by means of higher-layer messages, e.g., RRC configuration information, DCI/UCI signaling, MAC CE, LPP or pre-defined by the implementation.

[0138] According to certain embodiments, the assistance information for positioning may include, e.g., the spatial characteristics of the positioning resource sets, TRP coordinates, LOS/NLOS conditions, and positioning signals used per TRP.

[0139] According to certain embodiments, the capabilities information may contain, e.g., the support of one or multiple reference signals for positioning and any restrictions that may apply such as, e.g., the maximum and minimum supported velocities, the maximum number of TRPs, or the maximum number of slots to average velocity measurements.

[0140] According to certain embodiments, the WTRU (e.g., UE) capabilities information may be sent by the WTRU (e.g., UE) via higher-layer signaling during initial connection establishment, or via an uplink shared control or data channel, or a MAC CE.

[0141] According to certain embodiments, velocity may be estimated by obtaining the area of a subset of subcarriers of the power spectrum obtained after accumulating the power spectra of the random FM noise, and comparing it against pre-recorded values of the spectral area for different SNRs and velocities.

[0142] According to certain embodiments, estimation of the power spectra of the random FM noise may be done by performing a DFT of the instantaneous frequency of the received signal after removing the frequency components other than the subcarriers containing the reference signal for positioning.

[0143] According to certain embodiments, the DFT may be performed over the signal resulting from concatenation of the symbols comprising the reference signals for positioning after replacing the CP fields with a known signal value, or a value obtained by interpolation of the signal values before and after the CP field.

[0144] According to certain embodiments, the location uncertainty can be expressed as the x, y and z dimensions of a 3D figure representing the uncertainty area of the WTRU (e.g., UE) location.

[0145] According to certain embodiments, the positioning and the velocity measurements may be reported by the WTRU (e.g., UE) via an uplink shared control or data channel, or a MAC CE.

[0146] **WTRU tracking in LOS and NLOS conditions**

[0147] In an exemplary embodiment exemplified in **FIG. 5**, a network (e.g., positioning) node, such as, e.g., LMF in 5G NR, that controls a set of TRPs involved in the trajectory estimation of a UE, characterized by any of the following actions:

[0148] In a step 501, the network node (e.g., LMF) may obtain/select the number of TRPs involved in the trajectory estimation of a moving WTRU (e.g., UE) based on, e.g., their LOS/NLOS likelihood, signal to noise ratios, user velocities, etc.

[0149] In a step 502, the network node (e.g., LMF) may construct one or multiple reference signals for positioning based on, e.g., the LOS/NLOS likelihood, velocity, or the positioning resources consumption, wherein at least one signal is of block type to enable NLOS velocity estimation and at least one signal is of comb type to enable accurate LOS positioning.

[0150] In a step 503, the network node (e.g., LMF) may select the time intervals for transmission of the one or multiple reference signals for positioning based on, e.g., velocity, expected covered distance, or geographic information.

[0151] In a step 504, the network (e.g., the set of TRPs) may transmits and/or receive one or multiple reference signals for positioning.

[0152] In a step 505, the network node (e.g., LMF) may obtain reports containing positioning measurements (e.g., coordinates, velocity, and location uncertainty) from the UE.

[0153] In a step 506, the network node (e.g., LMF) may refine the WTRU (e.g., UE) coordinates based on velocity and/or the current or past positioning estimations and/or may adjust the BW of the block positioning signals based on the reported values of the measurement BW used by the WTRU (e.g., UEs).

[0154] According to certain embodiments, the network node (e.g., positioning) node can be a Location Management Function entity or a base station in 3GPP NR.

[0155] According to certain embodiments, the number of TRPs involved in the trajectory estimation may be obtained in such a way that the likelihood of having LOS conditions is maximized when using RSTD positioning techniques.

[0156] According to certain embodiments, the number of TRPs involved may be calculated to ensure reliable velocity estimation in NLOS by accumulating their power spectra of random FM noise for low SNR values and/or high velocities.

[0157] According to certain embodiments, a UL/DL reference signal for positioning with comb frequency structure may be selected for TRPs with high likelihood of being in LOS conditions, and with block frequency structure for TRPs with high likelihood of being in NLOS conditions.

[0158] According to certain embodiments, the time intervals for transmissions may be adjusted such that the rate of transmission of the one or multiple reference signals for positioning is higher for high user velocities, and vice versa.

[0159] According to certain embodiments, the time intervals for transmissions may be adjusted such that the distance covered by the device during the time elapsed between any two consecutive UL/DL reference signals for positioning is within the positioning resolution.

[0160] According to certain embodiments, the estimated position and user velocity may be obtained from measurements of the one or multiple reference signals for positioning received from the UE.

[0161] According to certain embodiments, the estimated position and user velocity may be obtained from reports sent by said WTRU (e.g., UE) after transmission of the one or multiple reference signals for positioning by said TRP or set of TRPs.

[0162] According to certain embodiments, the estimated position and the location uncertainty can be refined by the velocity estimation, by discarding the points within the location uncertainty area that cannot be reached by the WTRU (e.g., UE) at the estimated velocity, based on the current or past positioning estimates and the elapsed time since the last positioning occasion.

[0163] According to certain embodiments, the BW of the block positioning signals may be set equal to the maximum of the measurement BW values reported by the WTRU (e.g., UEs) in NLOS configured to measure on that positioning signal.

[0164] According to certain embodiments, the BW of the block positioning signals may be set equal to a very high value if some of the WTRU (e.g., UEs) configured to measure on that positioning signal are in LOS, irrespective of the measurement BW reported by other WTRU (e.g., UEs) in NLOS.

[0165] WTRU configuration and assistance information for positioning

[0166] In an example, the WTRU (e.g., UE) may receive configuration information for positioning from the network, including at least one of the following:

[0167] The configuration information for positioning from the network may include resource set ID(s) of the one or multiple positioning signals.

[0168] The configuration information for positioning from the network may include resource ID(s) of the one or multiple positioning signals.

[0169] The configuration information for positioning from the network may include time configurations of the one or multiple positioning signals, including any of: (1) slot offset; (2) starting symbol position; (3) number of symbols, or slots, for averaging measurements; and (4) relative time between the one or multiple positioning signals, e.g., expressed in symbols, slots, frames, etc.

[0170] The configuration information for positioning from the network may include frequency configurations of the one of multiple positioning signals, including any of: (1) comb offset; (2) cyclic shift; (3) starting RE position in frequency; (4) number of RBs; and (5) signal pattern (e.g., comb or block type, with the block portion comprising either the whole signal bandwidth or a specified portion of it).

[0171] The configuration information for positioning from the network may include repetition configurations of the one or multiple positioning signals, including any of: (1) resource Type (e.g., aperiodic, semi-persistent, periodic); (2) resource set periodicity for periodic and semi-persistent types; and (3) gaps between resources and number of repetitions within a resource set.

[0172] The configuration information for positioning from the network may include other configurations including any of: (1) power control configurations (e.g., Transmission power); (2)

pathloss configurations associated with a reference signal (e.g., DL-PRS, SS-block); (3) QCL information; (4) number of TRPs; and (5) TRP ID(s).

[0173] In an example, the WTRU (e.g., UE) may receive configuration information for positioning reporting from the network.

[0174] The configuration information for positioning reporting from the network may include triggering conditions for reporting, including at least one of the following as explained hereafter: (1) absolute or relative threshold T1 for the minimum number of LOS links; (2) absolute or relative threshold T2 for the minimum velocity; and (3) absolute or relative threshold T3 for the minimum SNR.

The configuration information for positioning reporting from the network may include repetition information for reporting including any of: report type (e.g., aperiodic, semi-persistent, periodic); and report periodicity for periodic and semi-persistent types (e.g., in number of symbols, slots, etc.).

[0175] The configuration information for positioning reporting from the network may include Positioning measurements to report including any of: (1) time-based measurements, e.g., RSTD, RTT, etc. per TRP; (2) angle-based measurements, e.g., AoD, AoA, etc. per TRP; (3) power-based measurements, e.g., RSRP per TRP; (4) WTRU (e.g., UE) coordinates without considering the velocity estimate; (5) WTRU (e.g., UE) coordinates refined by the velocity estimate, if measured by the WTRU (e.g., UE); (6) location uncertainty without considering velocity, e.g., expressed as the x,y,z dimensions of a parallelepiped or any other suitable 3D figure; and (7) location uncertainty refined by the velocity estimate, if measured by the WTRU (e.g., UE).

[0176] The configuration information for positioning reporting from the network may include Velocity measurements to report including any of: (1) a quantity related to the averaged instantaneous frequency spectrum, e.g., its central subcarrier, the area of a subset of subcarriers around the central one, etc.; and (2) estimated WTRU (e.g., UE) velocity.

[0177] In an example, the WTRU (e.g., UE) and the network may exchange WTRU (e.g., UE) capabilities information upon initial WTRU (e.g., UE) registration, including at least one of the following: (1) WTRU (e.g., UE) support of the one or multiple positioning signals; (2) maximum number of positioning TRPs; (3) maximum and minimum values of estimated velocities; and (4) maximum number of symbols or slots to average velocity measurements.

[0178] In another example, the WTRU (e.g., UE) may receive assistance information for positioning to help the WTRU (e.g., UE) in positioning, including at least one of the following: (1) spatial characteristics of the positioning resource sets (e.g., its azimuth, elevation, and beamwidth) of the one or multiple positioning signals; (2) TRP-wise geographical coordinates; (3)

TRP-wise indication of LOS/NLOS conditions; and (4) TRP-wise indication of the used positioning reference signal(s).

[0179] The positioning configuration, reporting configuration, and the WTRU (e.g., UE) capabilities may be exchanged through, e.g., semi-static RRC signaling, System Information, or dynamically via DCI or MAC CE. Positioning configuration and reporting configuration may happen upon WTRU (e.g., UE) registration to the network, e.g., after initial access, as well as the WTRU (e.g., UE) capabilities information exchange. Assistance information may be more dynamically updated by the network based on the different TRPs involved in positioning, and the channel conditions (LOS/NLOS and the channel's coherence BW), that evolves over time and may impact the positioning signal characteristics and the measurements to be taken by the UE.

[0180] Positioning error

[0181] In positioning applications, a parameter of fundamental importance is the RMS error of the positioning technique.

[0182] *RMS error in LOS*

[0183] Assuming LOS conditions, a mean squared positioning error $\varepsilon_{rms,LOS}^2$ in LOS conditions can be lower bounded by the Cramer-Rao Bound

$$\varepsilon_{rms,LOS}^2 \geq \frac{c^2}{B_{rms}^2 SNR}, \quad (1)$$

where c is the speed of light, SNR is the signal-to-noise ratio, and B_{rms} is the RMS bandwidth of the positioning signal expressed by

$$B_{rms}^2 = \frac{\int_{-\infty}^{\infty} (2\pi f)^2 |S(f)|^2 df}{\int_{-\infty}^{\infty} |S(f)|^2 df}. \quad (2)$$

[0184] From equation (1), the higher the bandwidth of the positioning signal, the lower the positioning error. The positioning resolution $\Delta\varepsilon$ is given by:

$$\Delta\varepsilon = \pm \frac{c}{2M\Delta f}, \quad (3)$$

where Δf is the subcarrier spacing in an OFDM-like multicarrier symbol, and M is the number of subcarriers in the signal.

[0185] *RMS error in NLOS*

[0186] The timing information may be impaired by the multipath propagation in non-line-of-sight (NLOS) scenarios. If there is not a dominant line-of-sight signal component with highest received power, timing measurements may be corrupted by stronger echoes with higher delays than the LOS component. The additional positioning error, $\Delta\varepsilon_{rms,NLOS}^2$, can be related to the extra propagation time in the presence of multipath, Δt_{prop}, and the timing uncertainty introduced by the channel's delay spread, τ_{rms}. Under the reasonable assumption that Δt_{prop} and τ are independent random variables, we can write:

$$\Delta\varepsilon_{rms,NLOS}^2 \cong c^2\mathbb{E}\left\{\left(\Delta t_{prop}+\tau\right)^2\right\} = c^2\left[\mathbb{E}\left\{\left(\Delta t_{prop}\right)^2\right\}+\tau_{rms}^2+2\mathbb{E}\{\Delta t_{prop}\tau\}\right]$$

$$= c^2\overline{\Delta t}_{prop}^2+\frac{c^2}{B_c^2}, \quad (4)$$

where $\overline{\Delta t}_{prop}^2 \triangleq \mathbb{E}\left\{\left(\Delta t_{prop}\right)^2\right\}$ is the mean squared value of the extra propagation time from multipath, and $B_c = 1/\tau_{rms}$ is the channel's coherence bandwidth. This error can be considered independent from the Cramer-Rao bound in equation (1), so their mean squared values can be added thus yielding an overall mean squared error:

[0187] $\varepsilon_{rms,NLOS}^2 \geq \frac{c^2}{B_{rms}^2 SNR}+c^2\overline{\Delta t}_{prop}^2+\frac{c^2}{B_c^2}$. (5)

[0188] The complex modulated symbols can be first detected by the receiver via correlations in the time or frequency domains to detect the TRP or WTRU (e.g., UE) identity. The channel frequency response (CFR) may then be acquired to detect a linear progressive phase between any two consecutive resource elements, whose channel responses can be assumed to be approximately the same.

[0189] *Adaptation of the signal's bandwidth to the channel's coherence bandwidth in NLOS*

[0190] In an example, a first positioning signal may have a bandwidth of M subcarriers. Any time delay z_0 with respect to the start of the symbol may be seen as a linear progressive phase in the DFT domain. When M is equal or smaller than the channel's coherence bandwidth, the channel is approximately flat over the signal's bandwidth and its impact reduces to a complex constant H_0, so:

$$DFT_M^{-1}\{R[k]\} = DFT_M^{-1}\left\{H_0 S[k]e^{\frac{-j2\pi k z_0}{M}}\right\} = H_0 s[m-z_0], \quad (6)$$

where DFT_M^{-1} denotes an M-point inverse DFT, $R[k]$ is the frequency-domain received signal, $S[k]$ is the frequency-domain transmitted signal, and $s[m]$ is its M-point time-domain counterpart. If the channel is approximately flat over the signal's bandwidth, then no other multipath components will be present regardless of the LOS/NLOS nature of the link. The last term in equation (5) thus vanishes and the positioning error is given by:

$$\left(\varepsilon_{rms,NLOS}^2\right)_1 \gtrsim \frac{c^2}{(B_{rms}^2)_1 SNR}+c^2\overline{\Delta t}_{prop}^2. \quad (7)$$

[0191] In another example, a second positioning signal may have a wider bandwidth that is much larger than B_c. In this case the error may be dominated by the second and third terms of equation (5) thus yielding

$$\left(\varepsilon_{rms,NLOS}^{2}\right)_{2} \gtrsim c^{2}\overline{\Delta t}_{prop}^{2} + \frac{c^{2}}{B_{c}^{2}}. \quad (8)$$

[0192] Comparing equations (7) and (8), when $(B_{rms})_{type2} \cong B_c$ and for SNR values above 0 dB, we can write:

$$\left(\varepsilon_{rms,NLOS}^{2}\right)_{2} \gtrsim \left(\varepsilon_{rms,NLOS}^{2}\right)_{1}. \quad (9)$$

[0193] Equation (9) illustrates the advantage of using positioning signals with a bandwidth that matches the channel's coherence bandwidth in NLOS conditions, as their positioning error can be equal or smaller than in other wideband signals while minimizing the amount of frequency resources used.

[0194] NLOS velocity estimation using block reference signals

[0195] *Use of block reference signals for velocity estimation*

[0196] In a solution, if a reference signal for positioning is considered with a block frequency structure, the receiver can first remove the known phases of the positioning sequences $s[n]$ (e.g., by multiplying it with their complex conjugates) and remove any frequency components other than those reserved for the positioning signal. Denoting $r[n]$ as the received signal containing only positioning signal, the result $\check{r}[n]$ just contains the random phase variations introduced by the channel:

$$\check{r}[n] = r[n] \exp -j \arg s[n]. \quad (10)$$

$\check{r}[n]$ only contains random FM noise caused by fading. The discrete instantaneous frequency of $\check{r}[n]$, denoted as $\dot{\theta}[n]$, can be determined by

$$\dot{\theta}[n] = \frac{1}{2\pi}(\theta[n] - \theta[n-1]), \theta[n] = \arg \check{r}[n], \quad (11)$$

and its spectrum is given by:

$$S_{\dot{\theta}}[k] = DFT\{\dot{\theta}[n]\}. \quad (12)$$

[0197] In Rayleigh frequency-flat fading channels comprising a single tap, the continuous-time power spectrum of the random FM noise $\left|S_{\dot{\theta}}(f)\right|^{2}$ exhibits an a-priori known shape with long tails that theoretically extend to infinity. However, most of the area is confined in a region bounded by the maximum Doppler frequency f_d in both axes, as given by equation (13):

$$f_d = f_c \frac{v}{c}. \quad (13)$$

[0198] The area within an ideal rectangle shown in **FIG. 6** is thus proportional to the square of the Doppler frequency, f_d^2. The long tails at both sides are proportional to $1/f$ and are caused by phase slips occurring during deep fades (i.e., sudden jumps from $-\pi$ to $+\pi$ and vice versa). In addition, sporadic phase slips caused by thermal noise introduce an additional noise floor as a function of SNR. These undesired effects can be minimized by restricting the integration limits to a small frequency region around the centre frequency, thus filtering out part of their contribution. As the random FM noise is an angular modulation, estimation gets degraded at and below the so-called threshold SNR usually taken as 10 dB. In some cases, the threshold SNR can be reduced by using threshold extension techniques that improve the estimation performance.

[0199] In some cases, channels having significant multipath may also sometimes have a small LOS component, e.g., from refraction and diffraction through obstacles, that gets so attenuated to the WTRU (e.g., UE) that the receiver may erroneously detect one of the stronger multipath components instead, hence impairing positioning. Such NLOS channels are Rician fading channels with an additional LOS contribution appearing in the form of a delta function located at the central frequency of the instantaneous frequency spectrum. In such cases, the LOS contribution may be pre-subtracted from the spectrum to not impair the area calculation for velocity estimation.

[0200] To a good approximation, flat-fading conditions are met when the signal bandwidth is equal or smaller than the channel's coherence bandwidth. Therefore, NLOS velocity estimation can be enabled by reference signals for positioning having a block frequency structure.

[0201] To illustrate this point in more detail, in some solutions the area of the discrete-time power spectrum $\left|S_{\dot{\theta}}[k]\right|^2$ can be calculated between $\pm\delta$ subcarriers around the central subcarrier to provide an estimate of the squared maximum Doppler frequency, as expressed by equation (14):

$$\sum_{k=DC-\delta}^{DC+\delta} \left|S_{\dot{\theta}}[k]\right|^2 \propto f_d^2, \quad (14)$$

where the symbol $\propto$ means "proportional to". The value of δ may be optimized so that it is larger than the maximum expected Doppler frequency expressed in subcarriers, but not too large so that some undesired $1/f$ noise can still be rejected. As an example, a user moving at 250 kmph yields a Doppler frequency of 925.9 Hz at a carrier frequency of 4 GHz (equation (12)), and δ may be selected such that the integration interval in equation (14) covers at least ±925.9 Hz around the DC subcarrier. As the channel is frequency-flat, the shape of the power spectrum will tend to that in **FIG. 6** if enough time is taken to ensure a statistically representative set of channel outcomes. The resulting area may be compared with the values in a pre-recorded curve, or a look-up table, for different SNRs.

[0202] The area calculation may be affected by thermal noise that introduces random fluctuations on the spectrum. Moreover, the instantaneous channel conditions may deviate from the uniform probability distribution of received signals in azimuth, as assumed by the ideal spectrum in **FIG. 6**. To alleviate this, in some solutions the area calculation may involve averaging the spectrum over multiple signal occasions over time. By doing so, part of the noise can be filtered out and statistical accuracy can be improved by performing measurements over multiple channel realizations and larger time periods, to better resemble the ideal spectrum.

[0203] *Measurements for NLOS velocity estimation with block reference signals*

[0204] Velocity measurements can be performed on the DL or UL of block reference signals.

[0205] In some solutions involving DL measurements, the WTRU (e.g., UE) may receive a subset of DL reference signals for positioning with block structure from several TRPs, in one or multiple occasions. The WTRU (e.g., UE) can estimate the power spectrum of the random FM noise at specific subcarriers after averaging it over the one or multiple occasions, and across the TRPs involved, and compare it with, e.g., a table of pre-stored values previously obtained as a function of SNR to yield a combined velocity estimate. Such measurements, or the estimated velocity, can then be reported to the network.

[0206] According to certain embodiments, for example, involving UL measurements, multiple TRPs may receive a subset of UL reference signals for positioning with block structure transmitted by the WTRU (e.g., UE) in one or multiple occasions. Each TRP may estimate the power spectrum of the random FM noise obtained at specific subcarriers after averaging it over the one or multiple occasions, as in the DL case. Measurements may then be forwarded by each TRP to a central entity, e.g., a LMF, that suitably combines them to yield a velocity estimate.

[0207] The block reference signal BW may be adapted by the network to the channel's coherence BW to minimize resource consumption, e.g., based on the CSI. If the signal BW is larger than the channel's coherence BW, the WTRU (e.g., UE) may restrict the measurement BW to be equal to the latter. The measurement BW used by the WTRU (e.g., UE) can be signaled to the network as part of the positioning report.

[0208] In case a block positioning signal is transmitted by a TRP that is shared by multiple WTRU (e.g., UEs) if all TRP-UE links are in NLOS, the network may configure the signal BW according to the maximum coherence BW of the TRP-UE links and each WTRU (e.g., UE) may then restrict the measurement BW for velocity estimation to be equal to its channel's coherence BW, reporting it back to the network.

[0209] In case a block positioning signal is transmitted by a TRP that is shared by multiple WTRU (e.g., UEs) if some TRP-UE links are in LOS while others are in NLOS, the network may configure the block signal with a high BW for accurate LOS positioning. WTRU (e.g., UEs) in NLOS may then restrict the measurement BW for velocity estimation to be equal to their channel's coherence BW, reporting it back to the network. Alternatively, the network may configure WTRU (e.g., UEs) in NLOS to use the block signal and WTRU (e.g., UEs) in LOS to use a positioning signal aimed for LOS conditions, e.g., of comb type.

[0210] In case a block positioning signal is transmitted by a WTRU (e.g., UE) that is received by multiple TRPs, the same criteria may be followed for selection of the signal BW and measurement BW by the network.

[0211] In all cases, WTRU (e.g., UEs) only need the proper assistance information about the presence of LOS/NLOS links and comb/block positioning signals to perform the appropriate actions.

[0212] Contrary to other state-of-the-art Doppler estimation techniques that involve the computation of long autocorrelations to yield the Doppler spectrum, in this approach the velocity estimation may only involve the accumulation of the squared magnitude of a few subcarriers at the DFT output of the instantaneous frequency signal. These outputs can be combined and averaged over multiple TRPs and/or occasions without the need to store long sequences of complex received samples.

[0213] *Minimum resolvable velocity*

[0214] The minimum resolvable velocity, or velocity resolution, attained in one symbol, Δv_{sym}, can be given by the expression:

$$\Delta v_{sym} = \pm \frac{c\Delta f}{2f_c}, \quad (15)$$

where f_c is the carrier frequency. In some cases, the velocity resolution may not be good enough to detect the smallest velocities in the system. If that happens, the receiver (UE or TRP) may concatenate the symbols containing a block reference signal prior to obtaining the instantaneous frequency spectrum. Doing so is equivalent to increasing the DFT window length, which therefore reduces the effective subcarrier spacing of the DFT samples. As an example, in a DL reference signal for positioning with a block frequency structure comprising N_{sym}^{Block} symbols with a CP of length N_{CP}, the velocity resolution in a positioning occasion $\Delta v_{occasion}$ becomes (see **FIG. 7**):

$$\Delta v_{occasion} = \pm \frac{c\Delta f}{2f_c\left(1+\frac{N_{CP}}{N}\right)N_{sym}^{Block}}. \quad (16)$$

[0215] The CP is usually discarded upon detection as it does not provide any useful samples. However, its duration may be considered so that the spectrum of the FM noise is correctly calculated via a DFT over the total window length $(N + N_{CP})N_{sym}^{Block}$. If the symbols only contain known reference signals (i.e., no other data signals are frequency-multiplexed), the CP fields can be reconstructed by the receiver and the known phases may be removed prior to obtaining the instantaneous frequency. However, if the symbols contain signal components other than positioning signals, the CP will be unknown and the receiver may have to replace it with, e.g., pre-defined signal samples or an interpolation of the values before and after the CP field. Doing so can minimize unexpected artifacts when obtaining the random FM spectrum.

[0216] In a solution, the network may adjust the number of symbols needed per positioning occasion depending on the required velocity resolution as given by equation (16). In case a positioning signal is shared by multiple WTRU (e.g., UEs), the network may configure the number of symbols according to the minimum velocity resolution needed for all of them.

[0217] The proposed methods for positioning can cope with the eventual presence of NLOS links between TRPs and the UE. The benefits of the methods described in this proposal are any of the following elements.

[0218] Positioning in NLOS conditions is currently not exploited and can incur significant resources consumption from the TRPs and positioning resources unused.

[0219] Positioning can be enriched by incorporating multiple positioning signals with potentially different signal structures that allow for both position and velocity estimations in NLOS conditions.

[0220] The amount and time-frequency location of the resources used in NLOS positioning may be adapted to the actual channel conditions and resolution needed for positioning and velocity estimations.

[0221] These estimates can be beneficial in setting anticipatory actions for some RRM procedures like, e.g., beam tracking, handover prediction, beam failure recovery, etc. that may take advantage of approximately knowing the user position over time in NLOS conditions.

[0222] **WTRU (e.g., UE) measurements for positioning in LOS and NLOS conditions**

[0223] This section describes the measurements to be performed by the WTRU (e.g., UE) on the one or multiple reference signals for positioning in LOS and NLOS.

[0224] The WTRU (e.g., UE) may be (e.g., first) assumed to exchange the positioning configuration with the network including, e.g., the one or multiple positioning signal structures, time information, beam spatial characteristics, reporting configuration, etc. This information can configure the WTRU (e.g., UE) with certain positioning signal characteristics, triggers for reporting, and reporting quantities when performing positioning and/or velocity estimations. Configuration can be provided to the WTRU (e.g., UE) via, e.g., semi-static RRC signaling, System Information, or dynamically via, DCI or MAC CE.

[0225] The WTRU (e.g., UE) may (e.g., also) send a capabilities information message via RRC signaling to inform the network about the WTRU (e.g., UE) capabilities, e.g., support of positioning signals, maximum and minimum estimated velocities, etc. Both configuration and capabilities can happen upon initial network registration by the UE.

[0226] The assistance information provided to the WTRU (e.g., UE) may contain more dynamic information, e.g., the TRPs and positioning signals involved, a LOS/NLOS indication per TRP, etc. In one example, the WTRU (e.g., UE) may be dynamically configured to receive one or multiple positioning signals of different characteristics, e.g., some of them with a comb structure and others with a block structure.

[0227] *Rationale for velocity estimation in NLOS*

[0228] In some cases, some of the TRP-UE links may be partially or totally obstructed, while others may be in line of sight. Obstructed links lead to a significant loss in positioning accuracy. If some of the positioning signals are of block type, additional velocity estimates can be obtained from them together with the positioning estimates to better help the network locate the UE. Estimates of position and velocity on block-type signals may have the best possible accuracy, and the least possible resources consumption, when the signal BW used for measurements is equal to the channel's coherence BW. Hence, if the signal BW is larger than the channel's coherence BW the WTRU (e.g., UE) may perform measurements only over a measurement BW equal to the channel's coherence BW. The WTRU (e.g., UE) may signal to the network the measurement BW employed within the positioning reports, expressed as a binary flag (e.g., equal to 'signal BW' or 'channel's coherence BW'), or an absolute number of RBs, of the start and end RB for measurements, so that the network can optimize positioning resources accordingly.

[0229] In some cases, position and velocity measurements can be fused by the WTRU (e.g., UE) to better improve the location accuracy before reporting it to the network. As an example, the WTRU (e.g., UE) may store a certain number of position coordinates and velocities estimated from a certain past time until present. Position coordinates may have significant inaccuracy when obtained in NLOS conditions, but the presence of a velocity estimate may help narrow down the uncertainty area around each position measurement by simply discarding those coordinate that are at distances that cannot be reached by the WTRU (e.g., UE) at the current velocity. Fusion of position and velocity may then be performed at the WTRU (e.g., UE) to reduce the location uncertainty around the estimated coordinates. The refined location uncertainty may be reported by the WTRU (e.g., UE) as part of the positioning report. **FIG. 8** illustrates the refined location uncertainty that can be achieved at any time instant based on previous location and velocity estimates. The circled area around P_{n-1} represents the set of WTRU (e.g., UE) locations that can be reachable at velocity v after a time interval ΔT equal to the elapsed time since the last positioning occasions. Intersection of the circle with the location uncertainty obtained at time instant n may refine the current WTRU (e.g., UE) location uncertainty and, eventually, the current WTRU (e.g., UE) coordinates.

[0230] *Measurement procedure*

[0231] The UE, upon receiving the one or multiple positioning signals, may perform measurements according to the following steps:

[0232] The WTRU (e.g., UE) identifies the frequency structure of the positioning signals based on any of the following: (1) the frequency configuration of the one or multiple positioning signals included in the configuration step; (2) the time configuration and repetitions of the one or multiple positioning signals included in the configuration step; (3) blind detection (or semi-blind) of the frequency pattern of the signal, i.e., whether it has a comb or block structure; and (4) blind detection (or semi-blind) of the time pattern of the signal, e.g., by identifying a time periodicity that is indicative of a comb frequency structure.

[0233] If the WTRU (e.g., UE) is configured to position itself, it can perform positioning measurements (e.g., RSTD, RTT, RSRP, beam id, AoD, AoA) and obtain the location uncertainty. Location uncertainty may be obtained from, e.g., the geometrical dilution of precision.

[0234] If the WTRU (e.g., UE) is configured to report velocity and it detects at least one positioning signal with a block frequency structure, it can perform any of the following steps over a set of TRP-UE links determined by the triggering conditions, as explained below.

[0235] The WTRU (e.g., UE) may detect the one or multiple positioning signals having a block frequency structure, e.g., by correlating the frequency contents with the expected positioning sequences.

[0236] The WTRU (e.g., UE) may compensate the known phases of their complex symbols (e.g., by multiplying with their complex conjugates) and removes the frequency components outside the positioning resource blocks.

[0237] The WTRU (e.g., UE) may obtain the channel impulse responses (CIRs) per TRP and, for TRP links having a LOS indicator, removes the first signal path.

[0238] The WTRU (e.g., UE) may obtain a velocity estimation based on the following steps: the WTRU (e.g., UE) may concatenate the time-domain positioning symbols in a positioning occasion.

[0239] The WTRU (e.g., UE) may obtain a velocity estimation based on the following step: the WTRU (e.g., UE) may compare the signal BW with the channel's coherence BW obtained, e.g., from the CSI acquired by the UE: (1) if the signal BW is equal or smaller than the channel's coherence BW, the WTRU (e.g., UE) may perform measurements over the whole signal BW; (2) if the signal BW is higher than the channel's coherence BW, the WTRU (e.g., UE) may perform measurements only over the resources spanning a coherence BW.

[0240] The WTRU (e.g., UE) may obtain a velocity estimation based on the following step: if symbols contain signal components other than positioning signals, the WTRU (e.g., UE) may replace the received cyclic prefixes with any of the following: a pre-defined signal value (constant or variable); and an interpolated value based on the values before and after the CP.

[0241] The WTRU (e.g., UE) may obtain a velocity estimation based on the following steps: the WTRU (e.g., UE) may obtain the instantaneous frequency spectrum, e.g., by performing a DFT of the signal that results after obtaining the instantaneous frequency of the concatenated symbols.

[0242] The WTRU (e.g., UE) may obtain a velocity estimation based on the following step: the WTRU (e.g., UE) may average out the instantaneous frequency spectra across the TRPs involved over the symbols in a positioning occasion and the number of slots configured for velocity estimation.

[0243] The WTRU (e.g., UE) may obtain a velocity estimation based on the following step: the WTRU (e.g., UE) may obtain a velocity estimate based on, e.g., comparing any of the following quantities with a set of pre-recorded values obtained as a function of velocity and SNR: (1) the value of the central subcarrier of the spectrum; (2) the sum of a configured number of subcarriers around the central one of the spectrum; (3) the sum of all the subcarriers in the spectrum; and (4) any pre-defined operation applied to the subcarriers in the spectrum.

[0244] If the WTRU (e.g., UE) obtained a velocity estimation, it may use it together with any current or past positioning estimations to refine the current WTRU (e.g., UE) location and its location uncertainty by, e.g., discarding points that lie outside the reachable area of the WTRU (e.g., UE) considering its previous location at the current velocity.

[0245] The WTRU (e.g., UE) may determine to stop measuring velocity based on certain conditions, e.g.: (1) the WTRU (e.g., UE) is no longer configured to report velocity; (2) the WTRU (e.g., UE) no longer receives any positioning signal with a block frequency structure; and (3) the WTRU (e.g., UE) operational conditions advise not to make further velocity measurements, e.g., if the user detects that it does not move, when entering a tunnel, when running low of battery, etc.

[0246] The WTRU (e.g., UE) may determine to stop the positioning procedure, e.g., if the WTRU (e.g., UE) is no longer configured to position itself or if it no longer receives any positioning signal.

[0247] Measurements should be performed by the WTRU (e.g., UE) over the configured resources for positioning and reported back to the network in a periodic, semi-persistent or aperiodic form if triggering conditions are met. If the WTRU (e.g., UE) has not completed a measurement (e.g., a velocity estimation with a longer averaging time for block signals than for comb signals), it can avoid reporting it until it becomes available in a next reporting occasion.

[0248] WTRU reporting for positioning in LOS and NLOS conditions

[0249] This section describes the reporting procedures to be followed by the WTRU (e.g., UE) after positioning measurements are performed over the one or multiple reference signals for positioning.

[0250] In an example, the WTRU (e.g., UE) is first assumed to exchange configuration information for positioning, reporting, capabilities, and assistance information with the network. Upon reception of the one or multiple positioning signals, the WTRU (e.g., UE) performs positioning, or positioning and velocity measurements, according to the configuration received from the network and the type of positioning signals received (i.e., comb type or block type).

[0251] *Triggering conditions*

[0252] Triggering conditions may determine the measured quantities to include in the report after assessment of, e.g., the SNR of the links, the WTRU (e.g., UE) velocity, the presence of LOS/NLOS links, etc. Triggering conditions are provided to the WTRU (e.g., UE) as part of the positioning configuration.

[0253] According to certain embodiments, if the number of LOS links is above a threshold T1, then if velocity is estimated by the WTRU (e.g., UE) and its value is above another threshold T2, the WTRU (e.g., UE) may report positioning obtained from all the links, and velocity from the links transmitting block signals, if detected by the WTRU (e.g., UE). Velocity can in this case be beneficial for, e.g., prediction of MAC or RRM events like handovers, beam changes, etc.

[0254] According to certain embodiments, if the number of LOS links is above a threshold T1, then if velocity is estimated by the WTRU (e.g., UE) and its value is below T2, the WTRU (e.g., UE) may report only positioning information obtained from all the links, as very small velocity values may be subject to high imprecision.

[0255] According to certain embodiments, if the number of LOS links is below a threshold T1, the WTRU (e.g., UE) may report both positioning from all the links and velocity from the links transmitting block signals, if detected by the UE. The lack of positioning accuracy of NLOS links may be alleviated by the velocity estimates obtained from them that may help narrow down the WTRU (e.g., UE) location uncertainty and better guess the WTRU (e.g., UE) location.

[0256] According to certain embodiments, if the SNR of a given TRP-UE link is below a threshold T3, the WTRU (e.g., UE) may not obtain any position or velocity estimates from that link.

[0257] Irrespective of the above, the WTRU (e.g., UE) may report positioning measurements, velocity measurements, or both upon network request, e.g., via DCI or MAC CE. Similarly, the WTRU (e.g., UE) may stop reporting positioning upon network request.

[0258] *Reporting procedure*

[0259] After the WTRU (e.g., UE) performs measurements according to its configuration, the WTRU (e.g., UE) can follow the steps below for reporting:

[0260] According to certain embodiments, if triggering conditions are met, the WTRU (e.g., UE) may report: quantities related with positioning, considering any of the following: (1) time-based measurements, e.g., RSTD, RTT, etc. per TRP; (2) angle-based measurements, e.g., AoD, AoA, etc. per TRP; (3) power-based measurements, e.g., RSRP per TRP; (4) WTRU (e.g., UE) coordinates without considering the velocity estimate; (4) WTRU (e.g., UE) coordinates refined by the velocity estimate, if measured by the WTRU (e.g., UE); (5) location uncertainty without considering velocity, e.g., expressed as the x,y,z dimensions of a parallelepiped or any other suitable 3D figure; (6) location uncertainty refined by the velocity estimate, if measured by the WTRU (e.g., UE).

[0261] According to certain embodiments, if triggering conditions are met, the WTRU (e.g., UE) may report: quantities related with velocity, if estimated by the WTRU (e.g., UE), considering at least one of the following: (1) a quantity related to the averaged instantaneous frequency spectrum, e.g., its central subcarrier, the area of a subset of subcarriers around the central one, etc.; (2) estimated WTRU (e.g., UE) velocity; (3) TRP-wise measurement BW, e.g., expressed as a flag ('signal BW' or 'channel coherence BW'), or in number of RBs, or as the start and end RB.

[0262] According to certain embodiments, if triggering conditions are met, the WTRU (e.g., UE) may report positioning signals employed for each measurement, e.g., as a flag, sequence identifier, time stamp of reception (e.g., the symbol index, slot index, frame index, etc. in absolute or relative terms), etc.

[0263] According to certain embodiments, if triggering conditions are met, the WTRU (e.g., UE) may report actual reported quantities included, e.g., by means of a bit field or an explicit indication. Alternatively, the WTRU (e.g., UE) may signal the absence of any quantity in the report (e.g., lack of velocity when no block signals are detected, or a measurement not yet completed because of a longer time involved) by means of a pre-defined value in the corresponding field (e.g., zero).

[0264] The WTRU (e.g., UE) may send a positioning report with a periodicity given by the repetition information for reporting provided in the configuration phase (e.g., aperiodic, semi-persistent or periodic reporting, with a configured periodicity expressed in number of symbols, slots, etc. for the two latter cases).

[0265] The WTRU (e.g., UE) may determine to stop sending reports, e.g., if triggering conditions are not met, or upon network request, or the WTRU (e.g., UE) no longer receives at least one positioning signal.

[0266] Positioning reports can be sent by the WTRU (e.g., UE) to the network via UL control signaling, e.g., UCI, MAC-CE, PUSCH, PUCCH, etc.

[0267] Trajectory Estimation in LOS and NLOS conditions

[0268] In some cases, knowledge of the WTRU (e.g., UE) location may be important for managing radio resources in a more efficient way, e.g., for beam prediction or handover preparation, even in NLOS conditions where accuracy is not high:

[0269] Velocity estimation may be beneficial to narrow down the location uncertainty of the WTRU (e.g., UE) and better guess the actual WTRU (e.g., UE) location, as explained above. This can be performed at the WTRU (e.g., UE) side (and reported to the network), or, e.g., at the LMF side.

[0270] Velocity estimation may be beneficial in, e.g., predicting the next suitable beam for beam management or preparing handovers. Knowing the scalar velocity can narrow down the area where the WTRU (e.g., UE) is located, even if coarse positioning estimates are available, and further help the network refine candidate beams for beam switching or set up neighbor candidate cells for handovers.

[0271] According to certain embodiments, knowing an approximate trajectory may help the network foresee the presence of obstacles in the line of sight between the TRP and the UE, thereby triggering preventive actions like, e.g., setting up additional transmit/receive points in multi-TRP scenarios.

[0272] According to certain embodiments, trajectories may help the network predict the time-domain evolution of the channel state information, e.g., to better estimate the precoding matrices to be considered in single-user MIMO or multi-user MIMO.

[0273] In **FIG. 9**, a moving device connected to several TRPs can benefit from one or multiple positioning signals to estimate the WTRU (e.g., UE) trajectory, exemplified by a straight line in the figure. The network may, e.g., combine a first and a second positioning signals in the figure to maximize efficiency depending on the LOS/NLOS conditions of the links. As an example, a first comb-type signal, or set of signals, can be scheduled for those TRPs with high likelihood of being in LOS conditions, while a second block-type signal, or set of signals, can be scheduled for TRPs with high likelihood of being in NLOS conditions. In addition, the first signal may be restricted to periodical occurrences even at LOS conditions, to limit the overhead, while leaving the second signal for more frequent estimations of velocity given its lower resource consumption.

[0274] The number of positioning signal occasions per unit time can be adjusted by the LMF based on, e.g., velocity, LOS/NLOS likelihood, past knowledge of the WTRU (e.g., UE) positions, etc. according to any of the following.

[0275] The network may schedule some periodic positioning occasions for accurate positioning, e.g., with a comb-type positioning signal, and multiple positioning occasions in between with, e.g., a block-type signal for velocity estimation. The rate of occurrence of each positioning signal may depend on the WTRU (e.g., UE) velocity, past WTRU (e.g., UE) positions, LOS/NLOS occurrences, and the instantaneous, or averaged, SNR.

[0276] The number of signal occasions per unit time with block frequency structure may (e.g., need to) consider the SNRs and/or WTRU (e.g., UE) velocities to yield a desired velocity accuracy, as averaging signals over multiple positioning occasions can have a significant impact on accuracy.

[0277] The time elapsed between any two consecutive positioning signals may be selected such that the distance covered by the device at the current velocity falls within the desired positioning resolution.

[0278] The rate of positioning updates may use (e.g., also depend on), e.g., additional geographic information available to the system, such that prediction of future locations can be done at the estimated velocity with enough confidence.

[0279] **Enhanced positioning in LOS and NLOS conditions**

[0280] This section describes in more detailed methods and procedures for WTRU (e.g., UE) positioning in LOS and NLOS conditions aided by a multiplicity of positioning signals with possibly different frequency structures, e.g., comb-type or block-type.

[0281] The WTRU (e.g., UE), after the initial steps on the positioning configuration, reporting configuration, assistance information for positioning, and WTRU (e.g., UE) capabilities exchange with the network, may receive one or multiple positioning signals from TRPs in either LOS or NLOS conditions. The WTRU (e.g., UE) may perform positioning measurements and, for those signals having a block frequency structure, may obtain estimates of its velocity. The measurement BW used in this case may be different than the signal BW, and equal to the channel's coherence BW, if both happen to not be similar. If triggering conditions are met, the WTRU (e.g., UE) may send reports containing measurements for positioning, or positioning and velocity estimation. The WTRU (e.g., UE) may also report the positioning signals used for the different measurements together with the measurement BW used by the WTRU (e.g., UE) on the block type positioning signals.

[0282] In an exemplary embodiment exemplified in FIG. 4, the WTRU (e.g., UE) involved in positioning may perform the following steps:

[0283] In a step 401, the WTRU (e.g., UE) may receive configuration information for positioning from the network (e.g., resource ID(s), time configuration, frequency configuration, etc.).

[0284] In a step 402, the WTRU (e.g., UE) may receive configuration information on positioning reports (e.g., triggering conditions for reporting, repetition information, positioning and velocity measurements, signals employed, etc.).

[0285] In a step 403, the WTRU (e.g., UE) may exchange positioning capabilities information with the network (e.g., WTRU (e.g., UE) support, maximum number of TRPs, maximum and minimum velocities, maximum number of symbols or slots to average velocity measurements, etc.).

[0286] In a step 404, the WTRU (e.g., UE) may receive assistance information for positioning (e.g., spatial characteristics of the positioning beams, TRP coordinates, LOS/NLOS indications, etc.).

[0287] In a step 405, the WTRU (e.g., UE) may receive the one or multiple positioning signals and identifies their frequency structure (e.g., comb type or block type) based on, e.g., the frequency configuration, time configuration, blind detection, etc.

[0288] In a step 406, if the WTRU (e.g., UE) may be configured to report positioning, it performs positioning measurements on the one or multiple positioning signals (e.g., RSTD, RTT, RSRP, beam id, AoD, AoD, etc.) and obtains its location uncertainty.

Location uncertainty can be expressed, e.g., as the x,y,z dimensions of a parallelepiped or any other 3D figure that represents the location uncertainty area of the UE.

[0289] In a step 407, if the WTRU (e.g., UE) is configured to report velocity and it detects at least one positioning signal with a block frequency structure, it performs velocity measurements on the one or multiple block positioning signals.

[0290] Velocity can be estimated, e.g., from the instantaneous frequency spectrum of the signal obtained after concatenation of the symbols in a positioning occasion, averaging over the configured number of symbols or slots, and across the TRPs transmitting block positioning signals.

[0291] WTRU (e.g., UE) obtains refined values of the WTRU (e.g., UE) coordinates and location uncertainty based on, e.g., the velocity estimate and current or past positioning estimations.

[0292] In a step 408, if triggering conditions are met (e.g., velocity above a threshold, number of LOS links below or above a threshold, a network request, etc.), the WTRU (e.g., UE) may send a positioning report back to the network, for example via UL control signaling, e.g., UCI, MAC-CE, PUSCH, PUCCH, etc.

[0293] The positioning report may include information indicating quantities related with positioning (e.g., RSTD, RTT, AoA, AoD, etc.).

[0294] The positioning report may include information indicating Quantities related with velocity (e.g., averaged instantaneous frequency spectrum, estimated WTRU (e.g., UE) velocity, measurement BW, etc.), if estimated by the UE

[0295] The positioning report may include information indicating WTRU (e.g., UE) coordinates before and after refinement with the velocity estimate, if estimated by the WTRU (e.g., UE).

[0296] The positioning report may include information indicating WTRU (e.g., UE) location uncertainty before and after refinement with the velocity estimate, if estimated by the WTRU (e.g., UE).

[0297] The positioning report may include information indicating positioning signals employed for each measurement (e.g., using a flag, sequence identifier, time stamp of reception like, e.g., the symbol index, slot index, frame index, etc. in absolute or relative terms), and actual quantities being reported per TRP (e.g., using a bit field, a special indicator, etc.).

[0298] The positioning report may include information indicating actual reported quantities included, e.g., by means of a bit field or an explicit indication, or the WTRU (e.g., UE) may signal the absence of any quantity in the report by means of a pre-defined value in the corresponding field (e.g., zero).

[0299] Periodicity of the reports may be given by the repetition information for reporting provided in the configuration phase (e.g., aperiodic, semi-persistent or periodic reporting, with a configured periodicity expressed in number of symbols, slots, etc. for the two latter cases).

[0300] In a step 409, the WTRU (e.g., UE) may determine to stop the reporting based on certain conditions, e.g., if triggering conditions are not met, or upon network request, or the WTRU (e.g., UE) no longer receives at least one positioning signal.

[0301] The described procedure may be repeated between steps 404 and 409 so that WTRU (e.g., UE) continues to measure and report its positioning until the positioning procedure stops, e.g., if requested by the network (via DCI, MAC CE, etc.), or if at least one positioning signal is no longer received from the positioning TRPs.

[0302] **WTRU tracking in LOS and NLOS conditions**

In an exemplary embodiment exemplified in **FIG. 5**, a network (e.g., positioning) node, such as, e.g., LMF or gNB in 5G NR, controls a set of TRPs involved in the UL/DL positioning of a UE. The aim of this solution is to configure the positioning signals to estimate positioning of a moving WTRU (e.g., UE) in LOS and NLOS conditions by taking advantage of additional velocity estimates, e.g., to refine the WTRU (e.g., UE) coordinates and its location uncertainty, and aid in RRM functions like beamforming, beam management, handover, etc. The network can also adjust the signal BW of the block positioning signals based on the measurement BW reported by the UE.

[0303] In a step 501, the network node (e.g., LMF) may select the number of TRPs involved in the trajectory estimation of a moving WTRU (e.g., UE) based on, e.g., any of the following criteria: the likelihood of having LOS conditions at the TRP-UE links is maximized; and further averaging is enabled for positioning and velocity measurements from TRPs, especially at low SNR values and/or high velocities.

[0304] In a step 502, the network node (e.g., LMF) may construct one or multiple reference signals for positioning wherein at least one positioning signal is of block type to enable NLOS velocity estimation, and at least one signal is of comb type to enable accurate LOS positioning, based on, e.g., any of the following: comb positioning signals may be selected for TRPs with high

LOS likelihood, and block positioning signals for TRPs with high NLOS likelihood; and block positioning signals can be selected between consecutive positioning occasions with comb frequency structure to minimize resource consumption.

[0305] In a step 503, the network node (e.g., LMF) may select time intervals for transmission of the one or multiple reference signals for positioning, based on any of the following: (1) the number of signal occasions per unit time with block frequency structure may be calculated, e.g., to yield a desired velocity accuracy based on the current SNRs and/or WTRU (e.g., UE) velocities; (2) the time elapsed between two consecutive positioning signals may be such that the covered distance at the user velocity falls within the positioning resolution; and (3) the rate of positioning updates may consider additional geographic information available to the system, such that prediction of future locations can be done at the estimated velocity with enough confidence.

[0306] In a step 504, the network (e.g., the set of TRPs) may transmit and/or receive the one or multiple reference signals for positioning.

[0307] In a step 505, the network node (e.g., LMF) may obtain reports containing positioning measurements from the UE.

[0308] In a step 506, the network node (e.g., LMF) may refine the WTRU (e.g., UE) coordinates based on velocity and/or the current or past positioning estimations and/or may adjust the BW of the block positioning signals based on the reported values of the measurement BW used by the WTRU (e.g., UEs).

[0309] **FIG. 10** is a flowchart illustrating a representative method 1000 implemented by a WTRU 102 to enhance the loss in positioning accuracy of the WTRU 102.

[0310] Referring to FIG. 10, the representative method 1000 may include, at block 1010, receiving, from a network node, configuration information to perform positioning measurements of the WTRU 102. At block 1020, the WTRU 102 may receive, from the network node, one or more positioning signals. At block 1030, the WTRU 102 may perform positioning measurements over the one or more positioning signals based on the configuration information. At block 1040, the WTRU 102 may determine a location uncertainty of the WTRU based on the positioning measurements.

[0311] In certain representative embodiments, the representative method 1000 may comprise determining by the WTRU 102 a frequency structure of the one or more positioning signals; the WTRU 102 may perform velocity measurements over the one or more positioning signals based on the configuration information, for example, on condition that at least one positioning signal of the one or more positioning signals comprises a block frequency structure.

[0312] In certain representative embodiments, the representative method 1000 may comprise determining a frequency structure of the one or more positioning signals is based on any of: (1) a time and frequency configuration of at least one positioning signal of the one or more positioning signals, and (2) a blind or semi-blind detection.

[0313] In certain representative embodiments, the representative method 1000 may comprise sending, to the network node, a positioning report comprising any of: (1) the positioning measurements, (2) the velocity measurements, (3) the location uncertainty, and (4) the one more positioning signals employed for the measurements.

[0314] In certain representative embodiments, sending the positioning report is periodical, semi-periodical or aperiodic.

[0315] In certain representative embodiments, the representative method 1000 may comprise determining to stop sending the positioning report based on any of: (1) a triggering condition, (2) a network request, and (3) no reception of at least one positioning signal during a period of time.

[0316] **FIG. 11** is a flowchart illustrating another representative method 1100 implemented by a WTRU 102 to enhance the loss in positioning accuracy of the WTRU 102.

[0317] Referring to FIG. 11, the representative method 1100 may include, at block 1110, receiving, from a network node, configuration information to perform positioning measurements of the WTRU 102.

[0318] At block 1120, the WTRU 102 may receive, from the network node, one or more positioning signals.

[0319] At block 1130, the WTRU 102 may perform positioning measurements over the one or more positioning signals based on the configuration information.

[0320] At block 1140, the WTRU 102 may determine a first location uncertainty of the WTRU based on the positioning measurements.

[0321] At block 1150, the WTRU 102 may determine velocity measurements over the one or more positioning signals based on the configuration information.

[0322] At block 1160, the WTRU 102 may determine a second location uncertainty of the WTRU based on the first location uncertainty and the velocity measurements.

[0323] At block 1170, the WTRU 102 may send, to the network node, a positioning report comprising any of: (1) the positioning measurements, (2) the velocity measurements, (3) the first location uncertainty, and (4) the second location uncertainty.

[0324] In certain representative embodiments, the representative method 1100 may comprise any of the following steps: determining first coordinates of the WTRU based on the positioning measurements; determining second coordinates of the WTRU based on the first coordinates and the velocity measurements; and wherein the positioning report may comprise any of: the first coordinates, and the second coordinates.

[0325] In certain representative embodiments, the representative method 1100 may comprise determining a type of frequency structure of the one or more positioning signals; andwherein the velocity measurements may be estimated on condition that the type of frequency structure corresponds to a block type frequency structure.

[0326] In certain representative embodiments, determining the type of frequency structure of the one or more positioning signals may be based on any of: (1) a time and frequency configuration of at least one positioning signal of the one or more positioning signals, and (2) a blind or semi-blind detection.

[0327] In certain representative embodiments, the positioning report may comprise the one or more positioning signals employed for the measurements.

[0328] In certain representative embodiments, sending the positioning report may be periodical, semi-periodical or aperiodic.

[0329] In certain representative embodiments, the representative method 1100 may comprise: determining to stop sending the positioning report based on any of: (1) a triggering condition, (2) a network request, and (3) no reception of at least one positioning signal during a period of time.

[0330] In certain representative embodiments, the triggering condition may comprise any of: (1) a first comparison of the velocity measurements and a first threshold, (2) a second comparison of a number of line of sight links and a second threshold.

[0331] In certain representative embodiments, the first location uncertainty and/or second location uncertainty may be expressed as x, y and z dimensions of a 3D figure representing an uncertainty area of a location of the WTRU.

[0332] In certain representative embodiments, determining the velocity measurements may comprise obtaining an area of a subset of subcarriers of a power spectrum obtained after accumulating a power spectra of a random frequency modulated noise, and comparing the area of a subset of subcarriers with pre-recorded values of a spectral area for different signal to noise ratios and velocities.

[0333] **Conclusion**

[0334] Although features and elements are provided above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations may be made without departing from its spirit and scope, as will be apparent to those skilled in the art. No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly provided as such. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods or systems.

[0335] The foregoing embodiments are discussed, for simplicity, with regard to the terminology and structure of wireless communication capable devices, (e.g., radio wave emitters and receivers). However, the embodiments discussed are not limited to these systems but may be applied to other systems that use other forms of electromagnetic waves or non-electromagnetic waves such as acoustic waves.

[0336] It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting. As used herein, the term "video" or the term "imagery" may mean any of a snapshot, single image and/or multiple images displayed over a time basis. As another example, when referred to herein, the terms "user equipment" and its abbreviation "UE", the term "remote" and/or the terms "head mounted display" or its abbreviation "HMD" may mean or include (i) a wireless transmit and/or receive unit (WTRU); (ii) any of a number of embodiments of a WTRU; (iii) a wireless-capable and/or wired-capable (e.g., tetherable) device configured with, inter alia, some or all structures and functionality of a WTRU; (iii) a wireless-capable and/or wired-capable device configured with less than all structures and functionality of a WTRU; or (iv) the like. Details of an example WTRU, which may be representative of any WTRU recited herein, are provided herein with respect to FIGs. 1A-1D. As another example, various disclosed embodiments herein *supra* and *infra* are described as utilizing a head mounted display. Those skilled in the art will recognize that a device other than the head mounted display may be utilized and some or all of the disclosure and various disclosed embodiments can be modified accordingly without undue experimentation. Examples of such other device may include a drone or other device configured to stream information for providing the adapted reality experience.

[0337] In addition, the methods provided herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

[0338] Variations of the method, apparatus and system provided above are possible without departing from the scope of the invention. In view of the wide variety of embodiments that can be applied, it should be understood that the illustrated embodiments are examples only, and should not be taken as limiting the scope of the following claims. For instance, the embodiments provided herein include handheld devices, which may include or be utilized with any appropriate voltage source, such as a battery and the like, providing any appropriate voltage.

[0339] Moreover, in the embodiments provided above, processing platforms, computing systems, controllers, and other devices that include processors are noted. These devices may include at least one Central Processing Unit ("CPU") and memory. In accordance with the practices of persons skilled in the art of computer programming, reference to acts and symbolic representations of operations or instructions may be performed by the various CPUs and memories. Such acts and operations or instructions may be referred to as being "executed," "computer executed" or "CPU executed."

[0340] One of ordinary skill in the art will appreciate that the acts and symbolically represented operations or instructions include the manipulation of electrical signals by the CPU. An electrical system represents data bits that can cause a resulting transformation or reduction of the electrical signals and the maintenance of data bits at memory locations in a memory system to thereby reconfigure or otherwise alter the CPU's operation, as well as other processing of signals. The memory locations where data bits are maintained are physical locations that have particular electrical, magnetic, optical, or organic properties corresponding to or representative of the data bits. It should be understood that the embodiments are not limited to the above-mentioned platforms or CPUs and that other platforms and CPUs may support the provided methods.

[0341] The data bits may also be maintained on a computer readable medium including magnetic disks, optical disks, and any other volatile (e.g., Random Access Memory (RAM)) or non-volatile (e.g., Read-Only Memory (ROM)) mass storage system readable by the CPU. The computer readable medium may include cooperating or interconnected computer readable medium, which exist exclusively on the processing system or are distributed among multiple interconnected processing systems that may be local or remote to the processing system. It should be understood that the embodiments are not limited to the above-mentioned memories and that other platforms and memories may support the provided methods.

[0342] In an illustrative embodiment, any of the operations, processes, etc. described herein may be implemented as computer-readable instructions stored on a computer-readable medium. The computer-readable instructions may be executed by a processor of a mobile unit, a network element, and/or any other computing device.

[0343] There is little distinction left between hardware and software implementations of aspects of systems. The use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software may become significant) a design choice representing cost versus efficiency tradeoffs. There may be various vehicles by which processes and/or systems and/or other technologies described herein may be effected (e.g., hardware, software, and/or firmware), and the preferred vehicle may vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle. If flexibility is paramount, the implementer may opt for a mainly software implementation. Alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

[0344] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples include one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples may be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In an embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), and/or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, may be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein may be distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a CD, a DVD, a digital tape, a computer memory, etc., and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[0345] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein may be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system may generally include one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity, control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0346] The herein described subject matter sometimes illustrates different components included within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality may be achieved. Hence, any two components herein combined to achieve a particular functionality may be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated may also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated may also be viewed as being "operably couplable" to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0347] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0348] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, where only one item is intended, the term "single" or similar language may be used. As an aid to understanding, the following appended claims and/or the descriptions herein may include usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim including such introduced claim recitation to embodiments including only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"). The same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B." Further, the terms "any of" followed by a listing of a plurality of items and/or a plurality of categories of items, as used herein, are intended to include "any of," "any combination of," "any multiple of," and/or "any combination of multiples of" the items and/or the categories of items, individually or in conjunction with other items and/or other categories of items. Moreover, as used herein, the term "set" is intended to include any number of items, including zero. Additionally, as used herein, the term "number" is intended to include any number, including zero. And the term "multiple", as used herein, is intended to be synonymous with "a plurality".

[0349] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0350] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein may be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," "greater than," "less than," and the like includes the number recited and refers to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0351] Moreover, the claims should not be read as limited to the provided order or elements unless stated to that effect. In addition, use of the terms "means for" in any claim is intended to invoke 35 U.S.C. §112, ¶ 6 or means-plus-function claim format, and any claim without the terms "means for" is not so intended.

CLAIMS

What is claimed is:

1. A method implemented by a wireless transmit/receive unit (WTRU), the method comprising:

receiving, from a network node, configuration information to perform positioning measurements of the WTRU;

receiving, from the network node, one or more positioning signals;

performing positioning measurements over the one or more positioning signals based on the configuration information;

determining a first location uncertainty of the WTRU based on the positioning measurements;

determining velocity measurements over the one or more positioning signals based on the configuration information;

determining a second location uncertainty of the WTRU based on the first location uncertainty and the velocity measurements; and

sending, to the network node, a positioning report comprising any of: (1) the positioning measurements, (2) the velocity measurements, (3) the first location uncertainty, and (4) the second location uncertainty.

2. The method of claim 1, further comprising:

determining first coordinates of the WTRU based on the positioning measurements;

determining second coordinates of the WTRU based on the first coordinates and the velocity measurements; and

wherein the positioning report comprises any of: the first coordinates, and the second coordinates.

3. The method according to any of claims 1-2, further comprising:

determining a type of frequency structure of the one or more positioning signals; and wherein the velocity measurements are estimated on condition that the type of frequency structure corresponds to a block type frequency structure.

4. The method according to claim 3, wherein determining the type of frequency structure of the one or more positioning signals is based on any of: (1) a time and frequency configuration of

at least one positioning signal of the one or more positioning signals, and (2) a blind or semi-blind detection.

5. The method according to any of claims 1-4, wherein the positioning report comprises the one or more positioning signals employed for the measurements.

6. The method according to any of claims 1-5, wherein sending the positioning report is periodical, semi-periodical or aperiodic.

7. The method according to any of claims 1-5, further comprising:

determining to stop sending the positioning report based on any of: (1) a triggering condition, (2) a network request, and (3) no reception of at least one positioning signal during a period of time.

8. The method according to claim 7, wherein the triggering condition comprises any of: (1) a first comparison of the velocity measurements and a first threshold, (2) a second comparison of a number of line of sight links and a second threshold.

9. The method according to any of claims 1-8, wherein the first location uncertainty and/or second location uncertainty are expressed as x, y and z dimensions of a 3D figure representing an uncertainty area of a location of the WTRU.

10. The method according to any of claims 1-9, wherein determining the velocity measurements comprises obtaining an area of a subset of subcarriers of a power spectrum obtained after accumulating a power spectra of a random frequency modulated noise, and comparing the area of a subset of subcarriers with pre-recorded values of a spectral area for different signal to noise ratios and velocities.

11. A wireless transmit/receive unit (WTRU) comprising: a processor and a transmit/receive unit configured to:

receive, from a network node, configuration information to perform positioning measurements of the WTRU;

receive, from the network node, one or more positioning signals;

perform positioning measurements over the one or more positioning signals based on the configuration information;

determine a first location uncertainty of the WTRU based on the positioning measurements;

determine velocity measurements over the one or more positioning signals based on the configuration information;

determine a second location uncertainty of the WTRU based on the first location uncertainty and the velocity measurements; and

send, to the network node, a positioning report comprising any of: (1) the positioning measurements, (2) the velocity measurements, (3) the first location uncertainty, and (4) the second location uncertainty.

12. The WTRU of claim 11, further configured to:

determine first coordinates of the WTRU based on the positioning measurements;

determine second coordinates of the WTRU based on the first coordinates and the velocity measurements; and

wherein the positioning report comprises any of: the first coordinates, and the second coordinates.

13. The WTRU according to any of claims 11-12, further configured to:

determine a type of frequency structure of the one or more positioning signals; andwherein the velocity measurements are estimated on condition that the type of frequency structure corresponds to a block type frequency structure.

14. The WTRU according to claim 13, wherein the type of frequency structure of the one or more positioning signals is determined based on any of: (1) a time and frequency configuration of at least one positioning signal of the one or more positioning signals, and (2) a blind or semi-blind detection.

15. The WTRU according to any of claims 11-14, wherein the positioning report comprises the one or more positioning signals employed for the measurements.

16. The WTRU according to any of claims 11-15, wherein the positioning report is sent periodically, semi-periodically or aperiodically.

17. The WTRU according to any of claims 11-15, further configured to:

determine to stop sending the positioning report based on any of: (1) a triggering condition, (2) a network request, and (3) no reception of at least one positioning signal during a period of time.

18. The WTRU according to claim 17, wherein the triggering condition comprises any of: (1) a first comparison of the velocity measurements and a first threshold, (2) a second comparison of a number of line of sight links and a second threshold.

19. The WTRU according to any of claims 11-18, wherein the first location uncertainty and/or second location uncertainty are expressed as x, y and z dimensions of a 3D figure representing an uncertainty area of a location of the WTRU.

20. The WTRU according to any of claims 11-19, wherein the WTRU is further configured to determine the velocity measurements by obtaining an area of a subset of subcarriers of a power spectrum obtained after accumulating a power spectra of a random frequency modulated noise, and comparing the area of a subset of subcarriers with pre-recorded values of a spectral area for different signal to noise ratios and velocities.

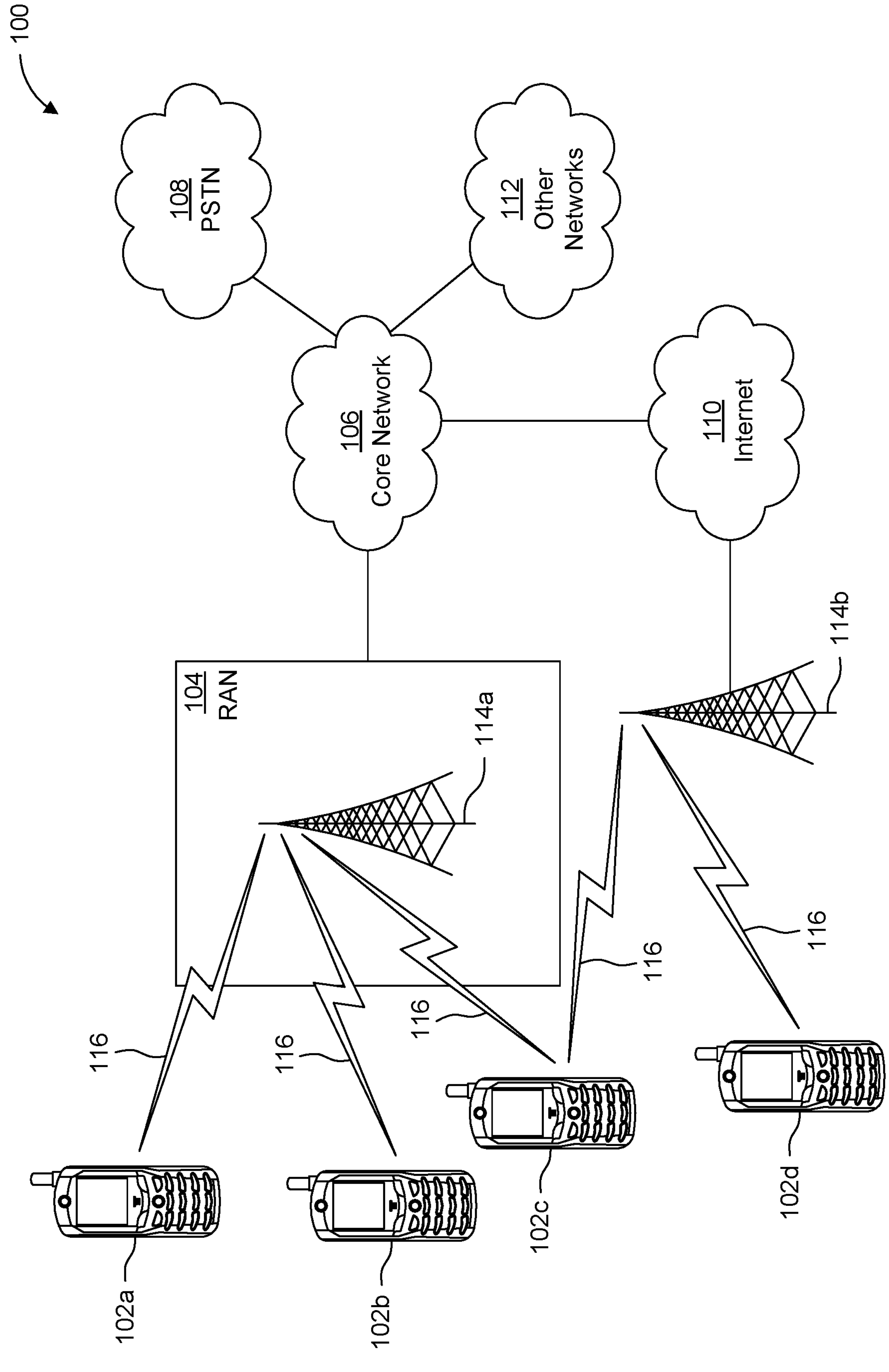

100
108
PSTN
112
Other
Networks
106
Core Network
110
Internet
104
RAN
114a
114b
116
116
116
116
116
102a
102b
102c
102d

FIG. 1A

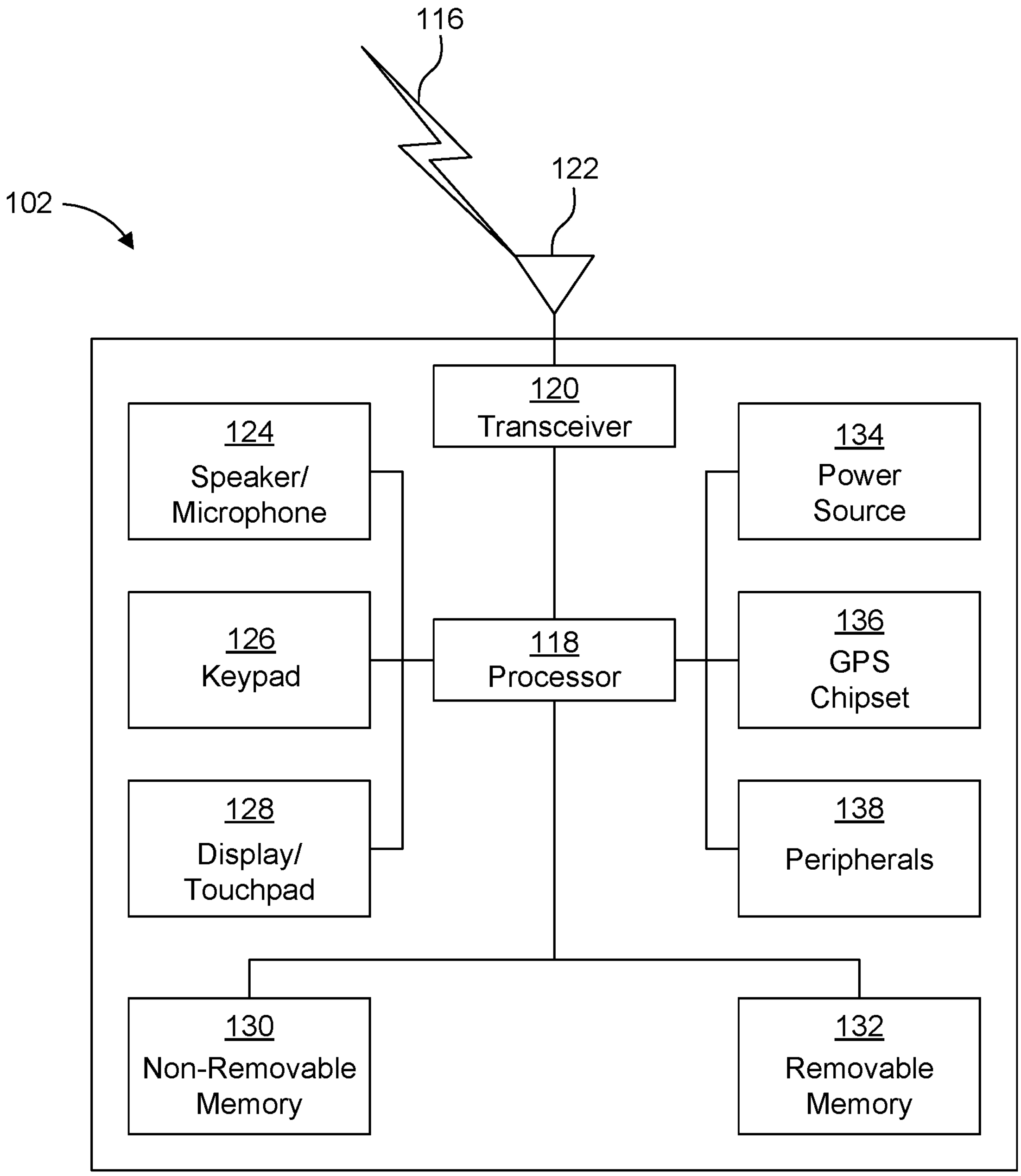

116
122
102
120
Transceiver
124
Speaker/
Microphone
126
Keypad
128
Display/
Touchpad
118
Processor
134
Power
Source
136
GPS
Chipset
138
Peripherals
130
Non-Removable
Memory
132
Removable
Memory

FIG. 1B

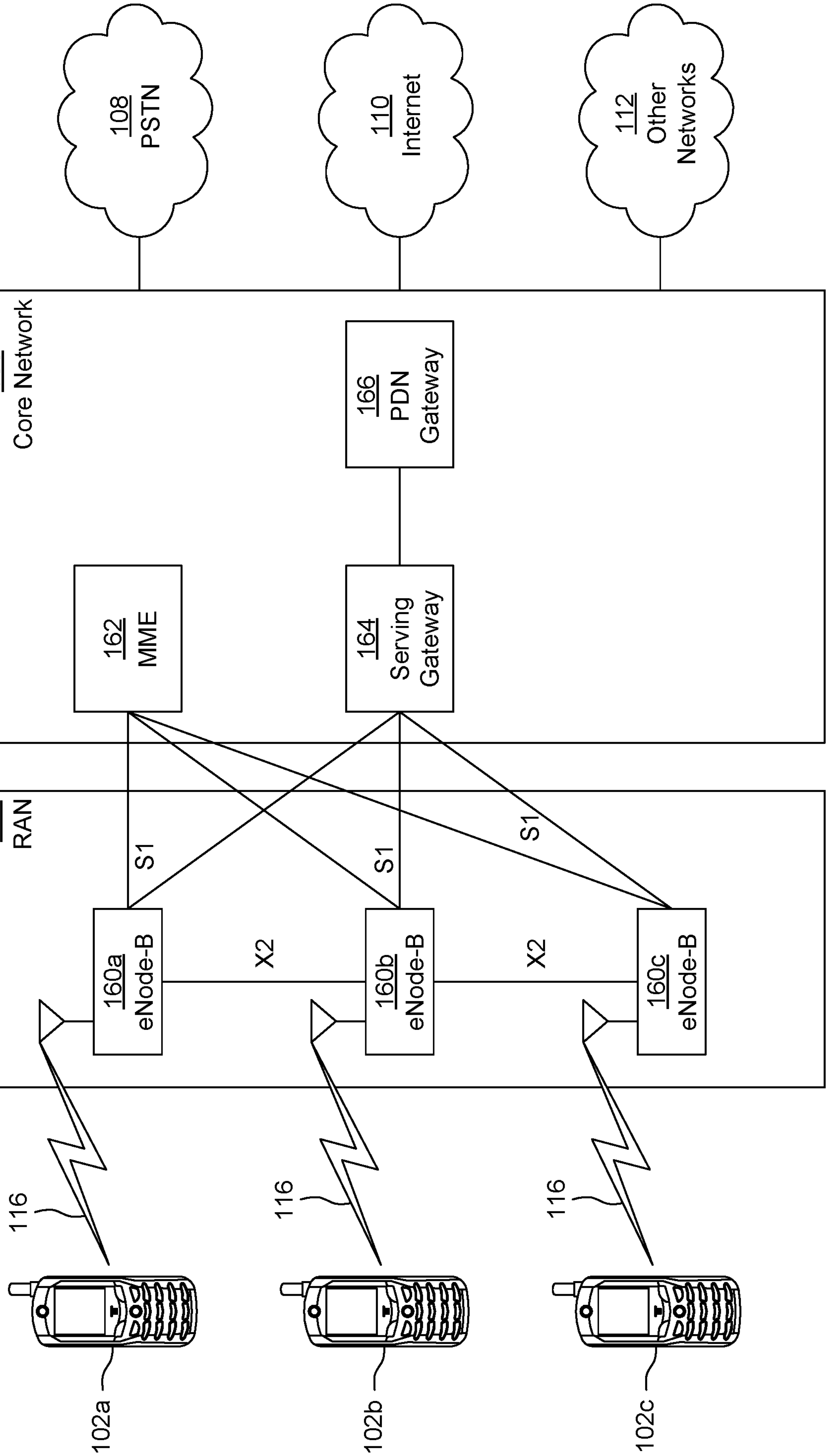
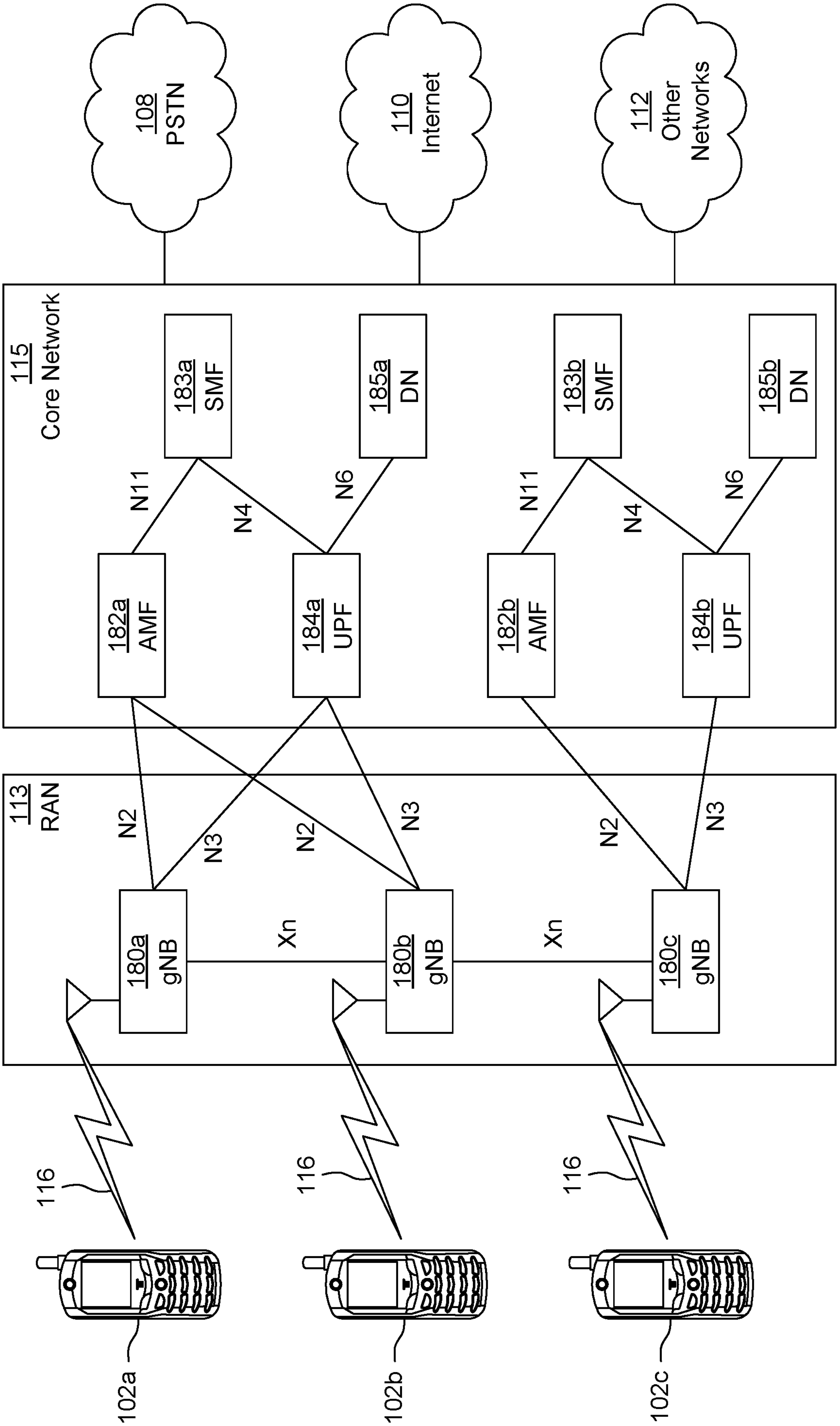

108
PSTN
110
Internet
112
Other
Networks
106
Core Network
162
MME
164
Serving
Gateway
166
PDN
Gateway
104
RAN
S1
S1
S1
160a
eNode-B
160b
eNode-B
160c
eNode-B
X2
X2
116
116
116
102a
102b
102c

FIG. 1C


108
PSTN
110
Internet
112
Other
Networks
115
Core Network
182a
AMF
183a
SMF
184a
UPF
185a
DN
182b
AMF
183b
SMF
184b
UPF
185b
DN
N11
N4
N6
N2
N3
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RAN
180a
gNB
180b
gNB
180c
gNB
116
102a
102b
102c

FIG. 1D

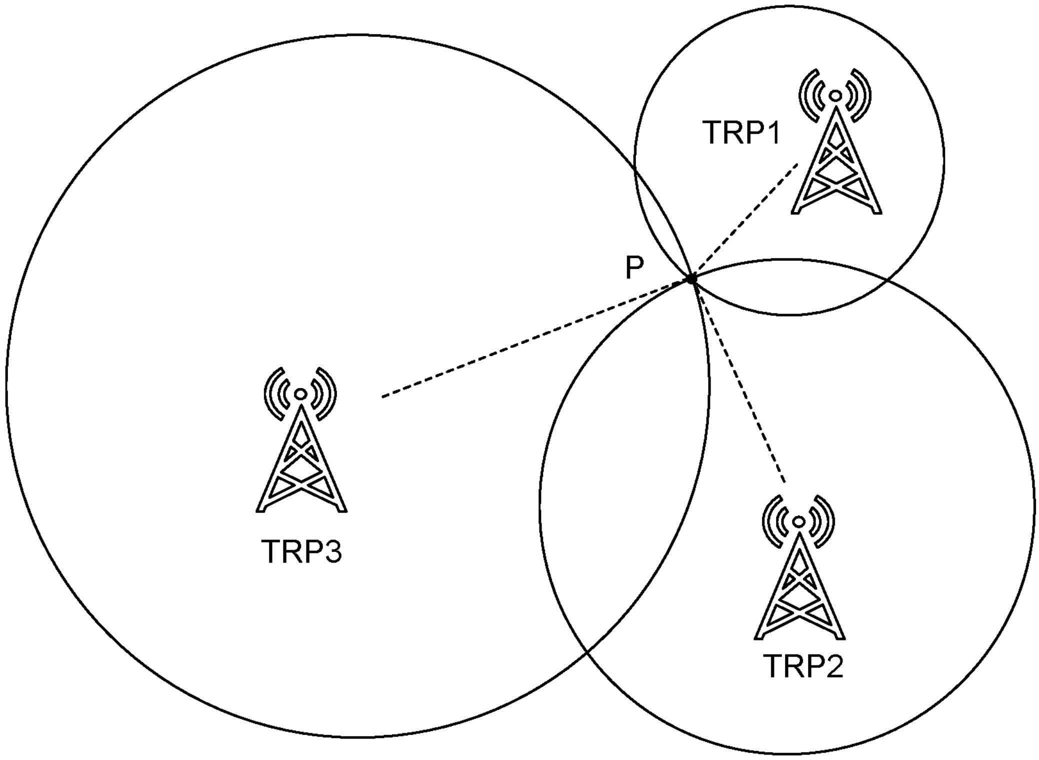


FIG. 2

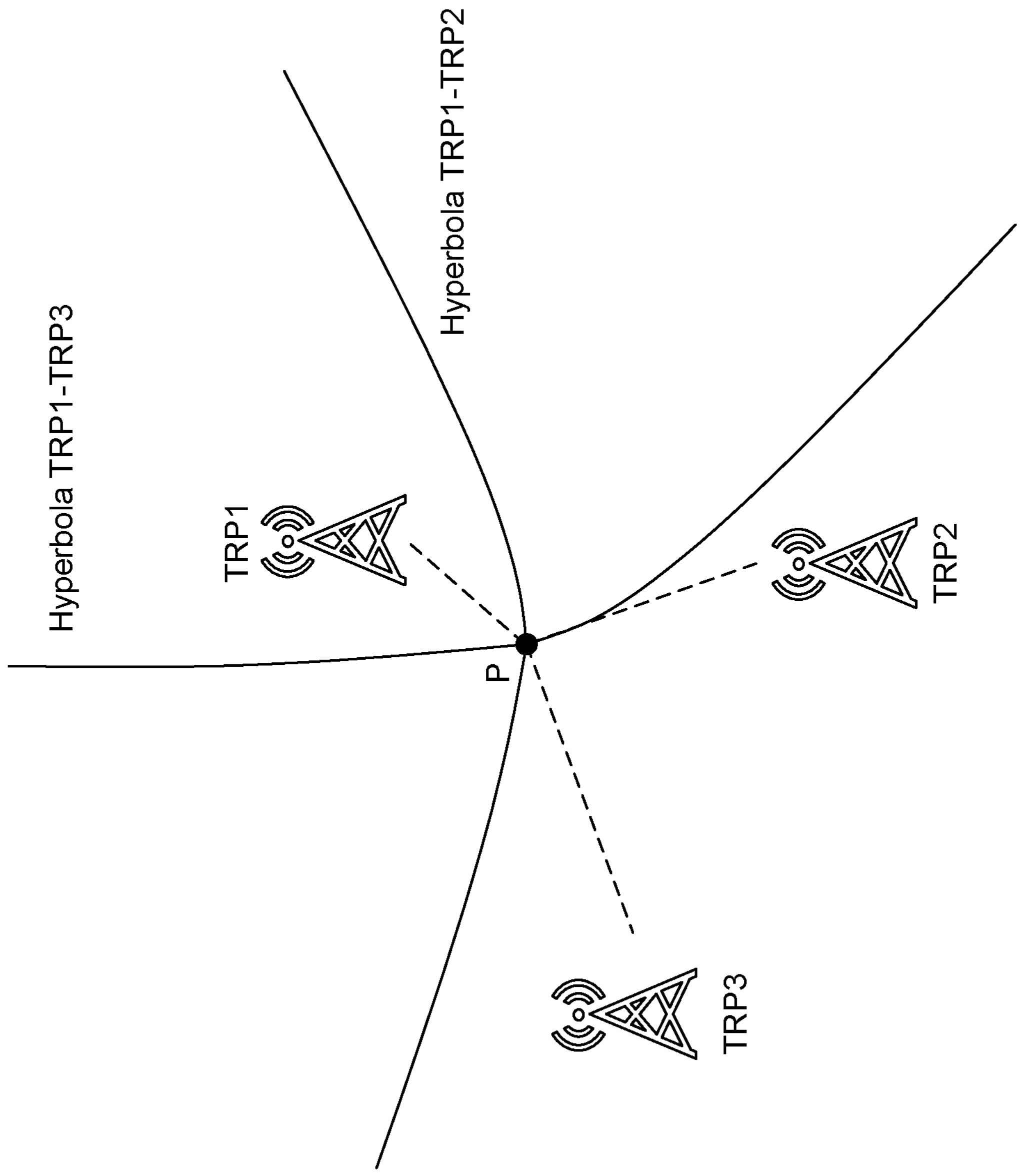


FIG. 3

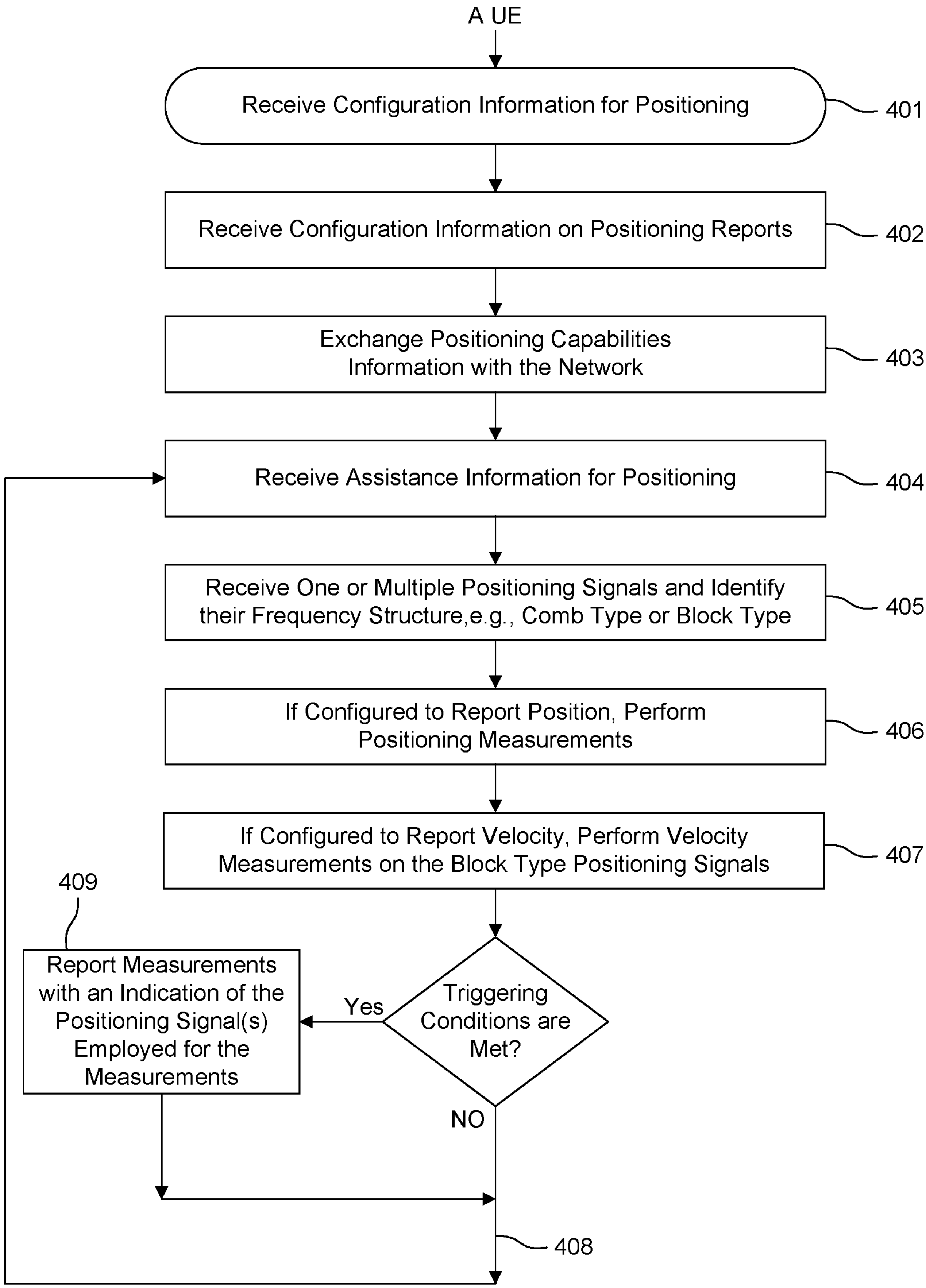

A UE
Receive Configuration Information for Positioning
401
Receive Configuration Information on Positioning Reports
402
Exchange Positioning Capabilities Information with the Network
403
Receive Assistance Information for Positioning
404
Receive One or Multiple Positioning Signals and Identify their Frequency Structure,e.g., Comb Type or Block Type
405
If Configured to Report Position, Perform Positioning Measurements
406
If Configured to Report Velocity, Perform Velocity Measurements on the Block Type Positioning Signals
407
409
Report Measurements with an Indication of the Positioning Signal(s) Employed for the Measurements
Yes
Triggering Conditions are Met?
NO
408

FIG. 4

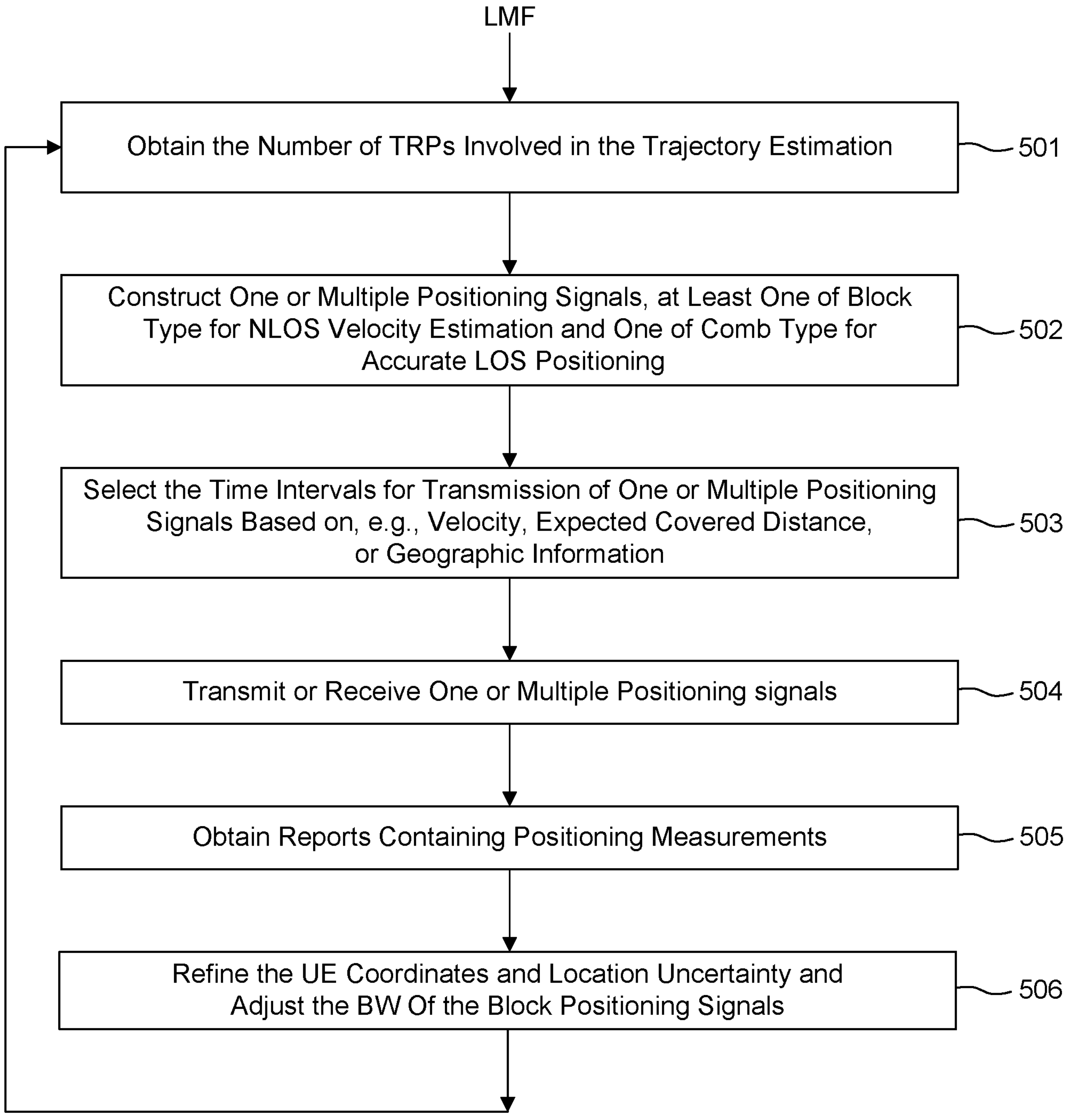
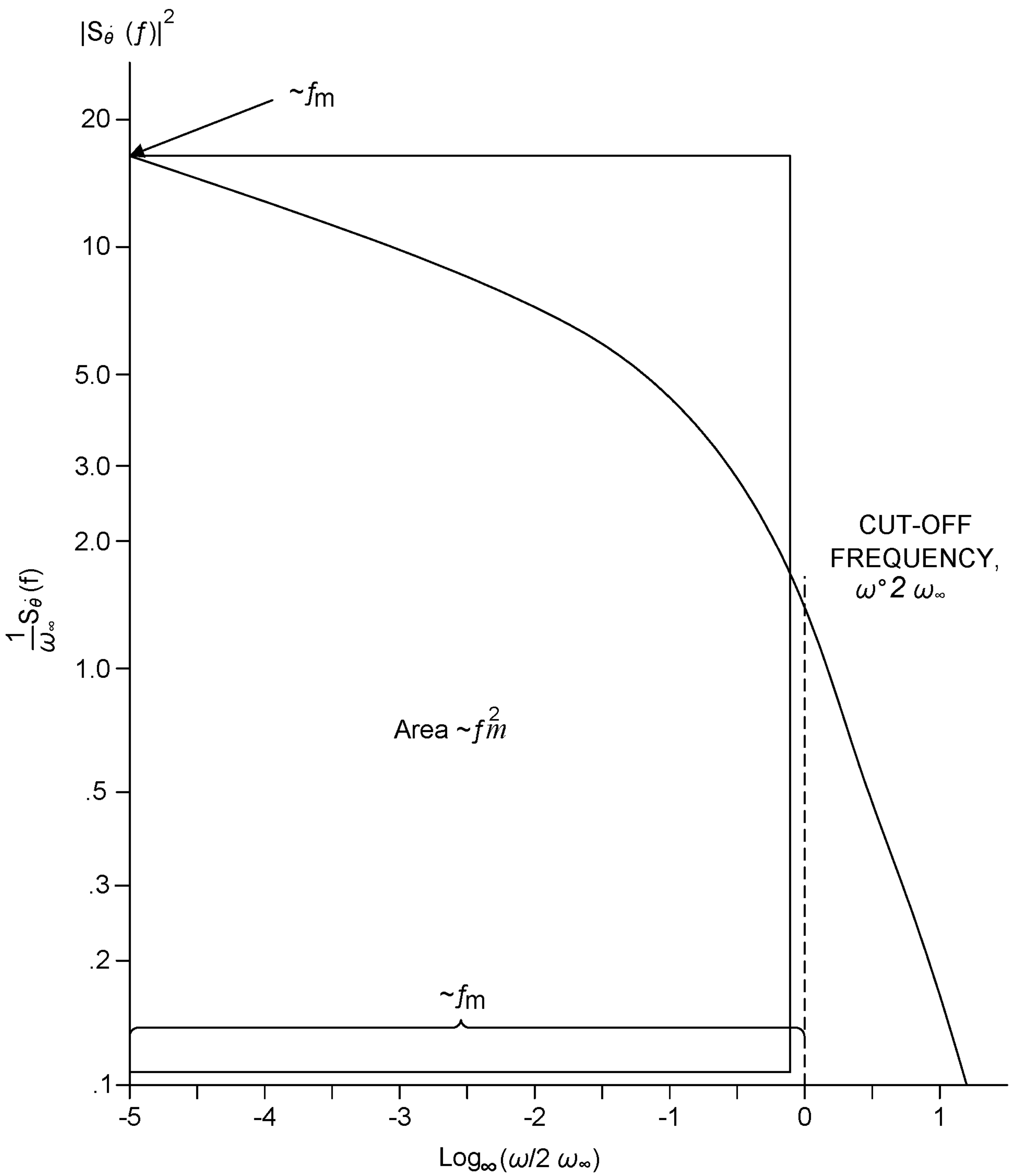

LMF
Obtain the Number of TRPs Involved in the Trajectory Estimation
501
Construct One or Multiple Positioning Signals, at Least One of Block Type for NLOS Velocity Estimation and One of Comb Type for Accurate LOS Positioning
502
Select the Time Intervals for Transmission of One or Multiple Positioning Signals Based on, e.g., Velocity, Expected Covered Distance, or Geographic Information
503
Transmit or Receive One or Multiple Positioning signals
504
Obtain Reports Containing Positioning Measurements
505
Refine the UE Coordinates and Location Uncertainty and Adjust the BW Of the Block Positioning Signals
506

FIG. 5



|S$_{\dot{\theta}}$ (f)|^2
~fm
20
10
5.0
3.0
2.0
1.0
.5
.3
.2
.1
$\frac{1}{\omega_\infty}$S$_{\dot{\theta}}$(f)
Area ~f^{2}m
CUT-OFF
FREQUENCY,
ω°2 ω∞
~fm
-5
-4
-3
-2
-1
0
1
Log∞(ω/2 ω∞)

FIG. 6

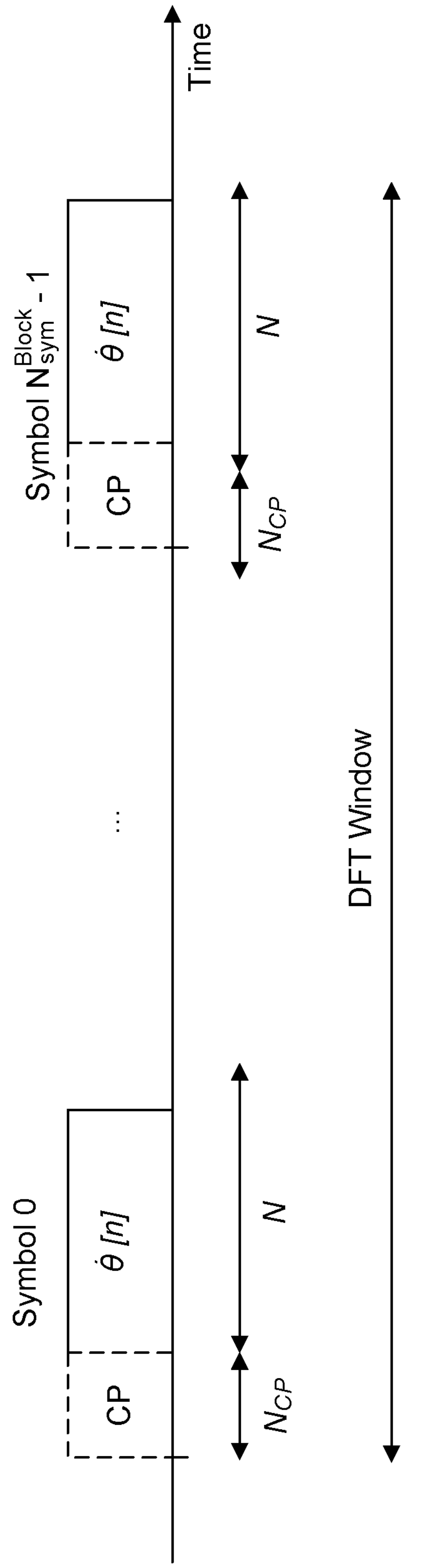

Time
Symbol N_{sym}^{Block} - 1
$\dot{\theta}\,[n]$
CP
N
N_{CP}
...
DFT Window
Symbol 0
$\dot{\theta}\,[n]$
CP
N
N_{CP}

FIG. 7

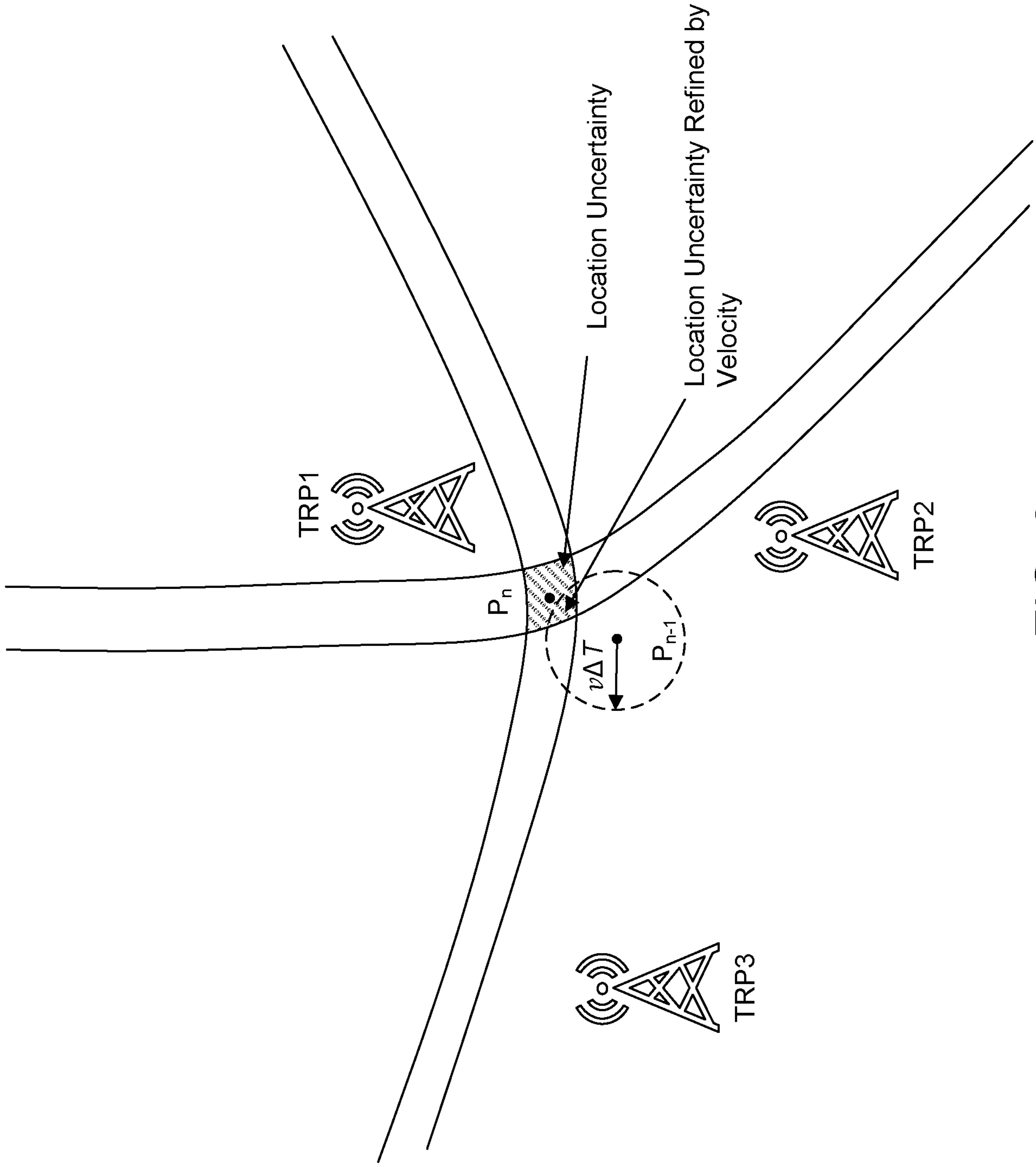

Location Uncertainty
Location Uncertainty Refined by Velocity
TRP1
TRP2
TRP3
P_n
P_{n-1}
$v\Delta T$

FIG. 8

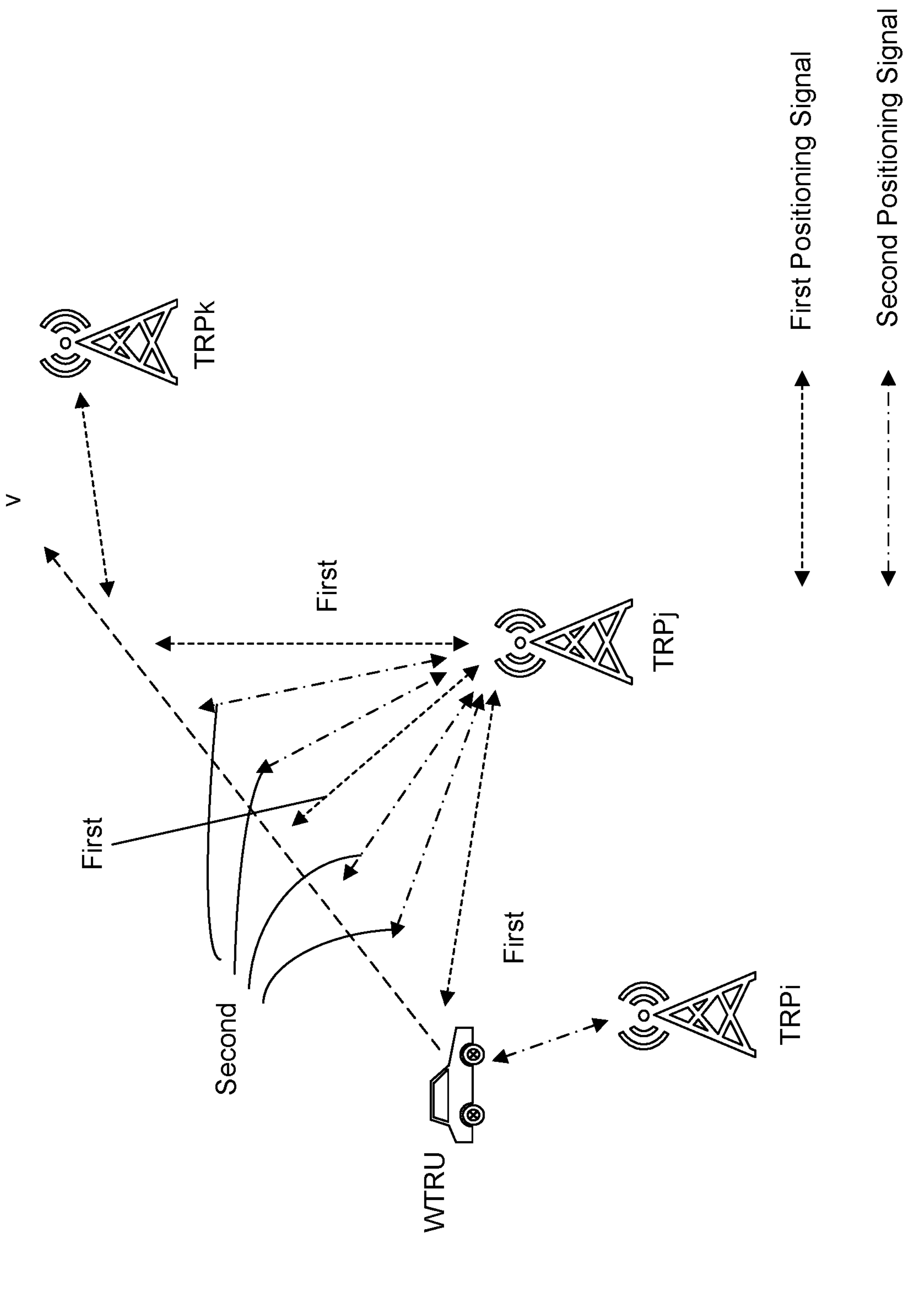

v
TRPk
First
TRPj
First
First
Second
WTRU
TRPi
First Positioning Signal
Second Positioning Signal

FIG. 9

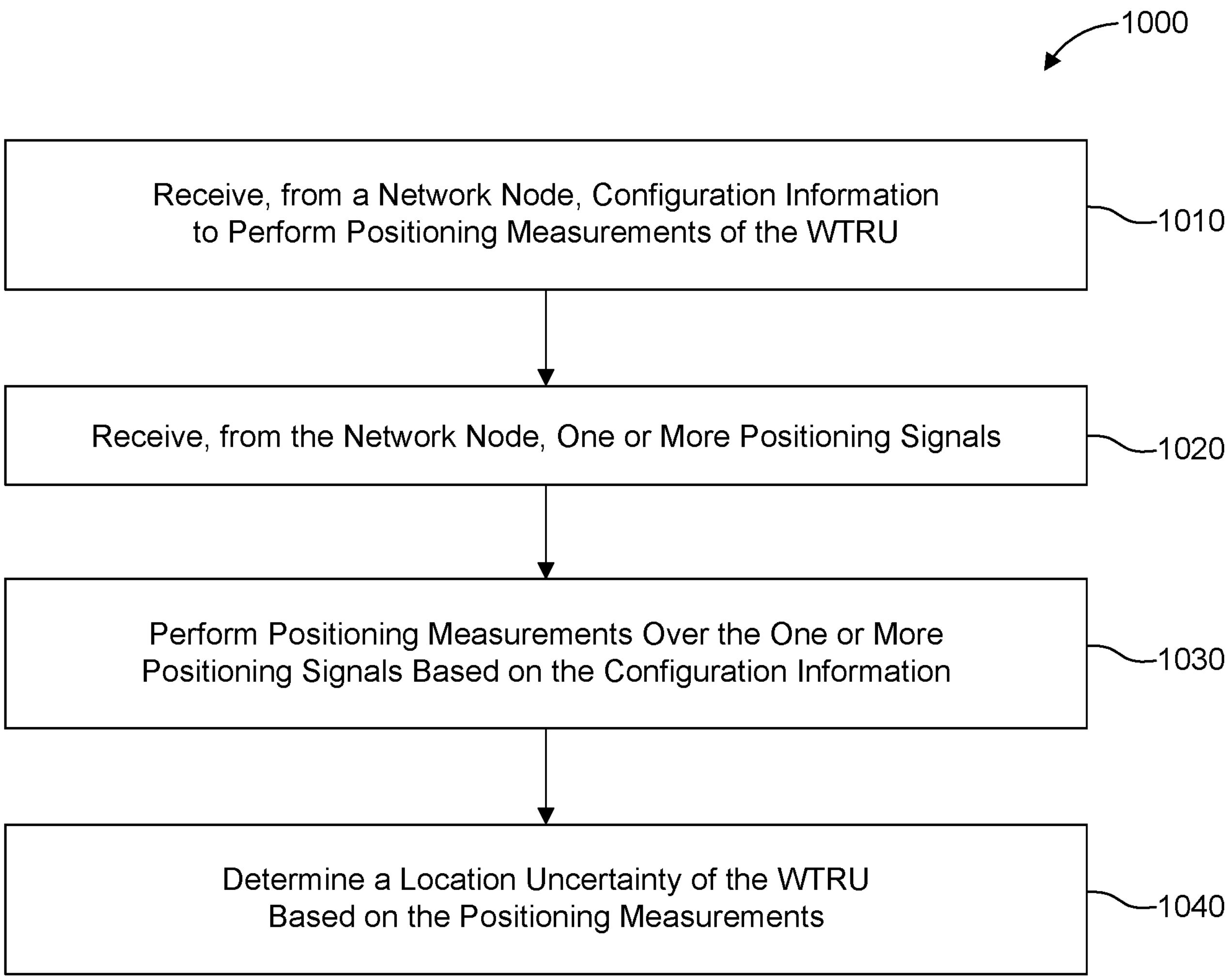

1000
Receive, from a Network Node, Configuration Information to Perform Positioning Measurements of the WTRU
1010
Receive, from the Network Node, One or More Positioning Signals
1020
Perform Positioning Measurements Over the One or More Positioning Signals Based on the Configuration Information
1030
Determine a Location Uncertainty of the WTRU Based on the Positioning Measurements
1040

FIG. 10

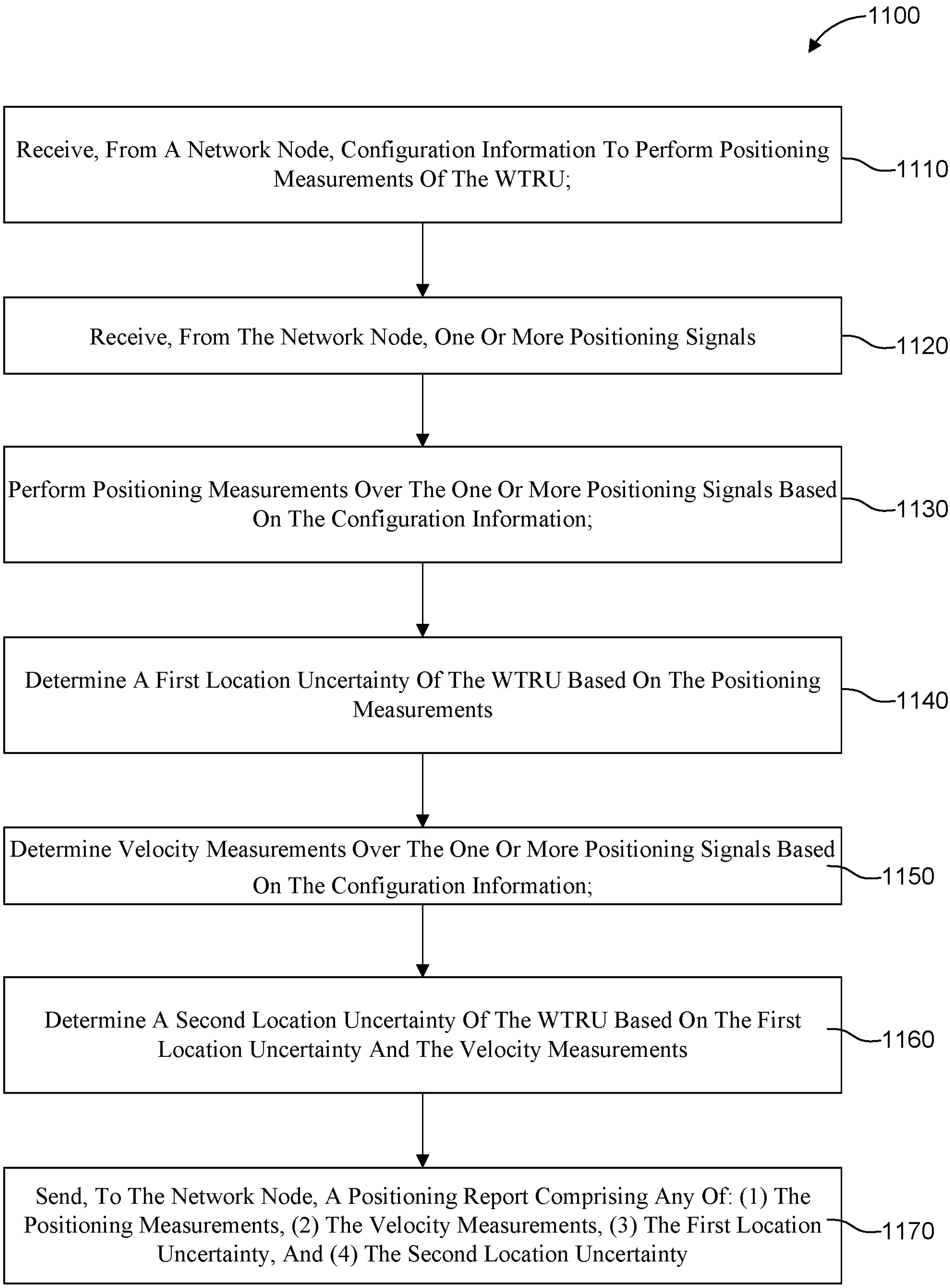

1100
Receive, From A Network Node, Configuration Information To Perform Positioning Measurements Of The WTRU;
1110
Receive, From The Network Node, One Or More Positioning Signals
1120
Perform Positioning Measurements Over The One Or More Positioning Signals Based On The Configuration Information;
1130
Determine A First Location Uncertainty Of The WTRU Based On The Positioning Measurements
1140
Determine Velocity Measurements Over The One Or More Positioning Signals Based On The Configuration Information;
1150
Determine A Second Location Uncertainty Of The WTRU Based On The First Location Uncertainty And The Velocity Measurements
1160
Send, To The Network Node, A Positioning Report Comprising Any Of: (1) The Positioning Measurements, (2) The Velocity Measurements, (3) The First Location Uncertainty, And (4) The Second Location Uncertainty
1170

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/031599

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S5/02 G01S11/10
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)
G01S

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

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

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 2019/166453 A1 (EDGE STEPHEN WILLIAM [US] ET AL) 30 May 2019 (2019-05-30) paragraphs [0042] - [0061], [0096] - [0134]; figures 2, 3,4, 11, 12 -----	1-20
A	US 2022/360943 A1 (EDGE STEPHEN WILLIAM [US] ET AL) 10 November 2022 (2022-11-10) paragraphs [0077] - [0119]; figures 3-6 -----	1-20

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

☒ See patent family annex.

* Special categories of cited documents :

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"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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2024	27/09/2024

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	Pariset, Nadia

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/031599

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019166453 A1	30-05-2019	US 2019166453 A1	30-05-2019
		WO 2019103804 A1	31-05-2019
US 2022360943 A1	10-11-2022	NONE	