TECHNIQUES FOR DETERMINING A PATH GROUP BASED ON A SENSING PROCEDURE

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to techniques for determining and reporting a path group based at least in part on a sensing procedure.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, which may be known as a network equipment (NE), supporting wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers, or the like)). Additionally, the wireless communications system may support wireless communications across various radio access technologies (RATs) including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., 5G-Advanced (5G-A), sixth generation (6G), etc.).

SUMMARY

[0003] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be

construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on.” Further, as used herein, including in the claims, a “set” may include one or more elements.

[0004] A radio node may be configured to, capable of, or operable to receive one or more sensing signals; perform a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration; determine path group based at least in part on the sensing procedure, where the path group includes multiple paths associated with one or more shared signaling path properties; and transmit a report that includes a set of one or more measurement quantities associated with the path group.

[0005] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to receive, at a radio node, one or more sensing signals; perform a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration; determine a path group based at least in part on the sensing procedure, where the path group includes multiple paths associated with one or more shared signaling path properties; and transmit a report that includes a set of one or more measurement quantities associated with the path group.

[0006] A method performed or performable by a UE for wireless communication is described. The method may include receiving one or more sensing signals; performing a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration; determining a path group based at least in part on the sensing procedure, where the path group includes multiple paths associated with one or more shared signaling path properties; and transmitting a report that includes a set of one or more measurement quantities associated with the path group.

[0007] A sensing measurement function (SensMF) for wireless communication is described. In some examples, the SensMF may implement, or may be implemented by, a UE or an NE. The SensMF may be configured to, capable of, or operable to transmit a sensing configuration for a sensing procedure, based on one or more sensing signals; receive a report

comprising a set of one or more measurement quantities associated with a plurality of paths; and associate the plurality of paths with a path group, where the path group includes a set of paths associated with one or more shared signaling path properties.

[0008] A processor for wireless communication is described. The processor may be configured to, capable of, or operable to transmit, from a SensMF, a sensing configuration for a sensing procedure, based on one or more sensing signals; receive a report comprising a set of one or more measurement quantities associated with a plurality of paths; and associate the plurality of paths with a path group, where the path group includes a set of paths associated with one or more shared signaling path properties.

[0009] A method performed or performable by a SensMF for wireless communication is described. The method may include transmitting a sensing configuration for a sensing procedure, based on one or more sensing signals; receiving a report comprising a set of one or more measurement quantities associated with a plurality of paths; and associating the plurality of paths with a path group, where the path group includes a set of paths associated with one or more shared signaling path properties.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0011] Figure 2 illustrates an example of a protocol stack in accordance with aspects of the present disclosure.

[0012] Figure 3 illustrates an example of near-field (NF) and far-field (FF) regions in accordance with aspects of the present disclosure.

[0013] Figure 4A illustrates an example of a first set of sensing scenarios for a radio sensing operation , in accordance with aspects of the present disclosure.

[0014] Figure 4B illustrates an example of a second set of sensing scenarios for a radio sensing operation, in accordance with aspects of the present disclosure.

[0015] Figure 5A illustrates an example of a tight coupling Information Sharing and Analysis Center (ISAC) network architecture, in accordance with aspects of the present disclosure.

[0016] Figure 5B illustrates another example of a tight coupling ISAC network architecture, in accordance with aspects of the present disclosure.

[0017] Figure 5C illustrates an example of an ISAC network architecture where the sensing function (SF) is co-located with the location management function (LMF), in accordance with aspects of the present disclosure.

[0018] Figure 5D illustrates an example of a loose coupling ISAC network architecture, in accordance with aspects of the present disclosure.

[0019] Figure 6 illustrates an example of a channel response of a human target in an NF sensing scenario in accordance with aspects of the present disclosure.

[0020] Figure 7 illustrates an example of a sensing scenario for determining multiple path groups based on the reception/measurement of sensing signal reflected from a human target in accordance with aspects of the present disclosure.

[0021] Figure 8 illustrates an example of a sensing scenario for determining a path group based on the reception/measurement of sensing signal reflected from a human target in accordance with aspects of the present disclosure.

[0022] Figure 9 illustrates an example of a sensing scenario for determining a path group and multiple subgroups based on the reception/measurement of sensing signal reflected from a human target in accordance with aspects of the present disclosure.

[0023] Figure 10 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0024] Figure 11 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0025] Figure 12 illustrates an example of an NE in accordance with aspects of the present disclosure.

[0026] Figure 13 illustrates a flowchart of a method performed by a radio node in accordance with aspects of the present disclosure.

[0027] Figure 14 illustrates a flowchart of a method performed by a SensMF in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0028] A wireless communication network, including one or more wireless devices, nodes, network entities, etc., may support sensing (also referred to as radio frequency (RF) sensing) to improve reliability and performance of the wireless communication network. Additionally, the one or more wireless devices, nodes, network entities, etc. may support sensing to enable various applications or services based on obtained sensing information from the one or more wireless devices, nodes, network entities, etc. The one or more wireless devices, nodes, network entities, etc., may perform sensing according to a sensing procedure, which may include one or more of sensing an environment (e.g., a physical environment, space, area), performing measurements according to the sensing, and generating (or obtaining) sensing information associated with a target entity (e.g., object, device, environment). The sensing information (also referred to as "sensing results") may include, but is not limited to, a position of the target entity, a velocity of the target entity, a direction (e.g., heading) of the target entity, an orientation of the target entity, a radar cross-section (RCS) of the target entity, a geometric shape of the target entity, a characteristic (e.g., material, composite, attribute, feature, etc.) of the target entity.

[0029] In some implementations, the sensing information may be obtained based on a sensing signal outputted (e.g., transmitted, reflected, backscattered) from one or more wireless devices, nodes, network entities. The sensing signal may be one or more of an uplink reference signal, a downlink reference signal, or a sidelink reference signal, or a combination thereof. For example, the sensing signal may be a channel state information reference signal (CSI-RS), a positioning reference signal (PRS), a sounding reference signal (SRS), or a sensing-dedicated reference signal (RS), among other examples. A wireless device, radio node, network entity configured to or operable to output a sensing signal may be referred to herein as a "sensing transmitter node" or "sensing transmitting node."

[0030] Additionally, or alternatively, in some other implementations, the sensing information may be obtained based on an obtained (e.g., received) sensing signal via the environment (e.g., reflected, refracted, scattered, blocked/attenuated, etc.), for example, by one or more wireless devices, nodes, network entities. A wireless device, radio node, network entity configured to or operable to obtain (e.g., receive) a sensing signal may be referred to herein as "sensing receiver node" or "sensing receiving node." In other implementations, additionally or alternatively, the sensing information may be obtained based on processing a received reflection of a sensing signal and/or inferring relevant information from the environment.

[0031] The measurement (e.g., sensing measurement) may involve one or multiple (static or mobile) sensing transmitter nodes with known sensing information or with (partially) unknown sensing information (e.g., known or unknown position). In some other implementations, the measurement (e.g., sensing measurement) may involve one or multiple (static or mobile) sensing receiver nodes with known or (partially) unknown sensing information (e.g., known or unknown position). In other implementations, the measurement (e.g., sensing measurement) may involve one or multiple (static or mobile) objects/reflectors with known or (partially) unknown sensing information (e.g., known or unknown position, presence, RCS, etc.).

[0032] In some implementations, the radio nodes (e.g., at least one sensing transmitter node and at least one sensing receiver node) may be capable of performing sensing transmission and reception for a target located at the NF region of one or more of the radio nodes. In such implementations, the NF focusing of the transmission/reception beams can be constructively utilizing the NF focusing of the transmission/reception beams can assist the sensing measurements, e.g., for detection and/or positioning of a sensing target object. Specifically, a spherical transmitter beam may generate a focus point/area. The NF beam pattern (e.g., of a spherical beam) is distinct from the FF beam pattern in that the NF beam pattern allows control with distance/depth dependency (in addition to the angle, which is the usual case in FF pattern).

[0033] This feature of the NF beam pattern may be useful for sensing applications. In addition to the angle-of-departure (AoD) and/or zenith-of-departure (ZoD) information, the

NF beam pattern also indicates the distance between the transmission point and the focus point. Hence, when sensing and/or monitoring an area at within the NF of a sensing transmitter node, the sensing controller may benefit from additional information to enable enhanced interpretation of the sensing measurement. Such additional information may include a description of the spherical/NF beam pattern, including details about the focus point/area.

[0034] In certain sensing scenarios, it is beneficial to perform (and report) sensing measurements using a sensing receiver node located within the NF of a reflector object (i.e., target object). The proximity of the sensing receiver node to the reflector leads to better observability (e.g., due to receiving more energy from the sensing signal(s)), and better capability of the sensing receiver node to discern/distinguish rays reflected from different parts of the reflector object. In such scenarios, where the sensing receiver node is capable of a high-resolution temporal measurements (e.g., large bandwidth) and angular measurements (e.g., large antenna/array aperture), it may be beneficial to measure and/or report on requires measurement/report of a group of distinct paths (or rays or multi-path components (MPCs)). As an example, the sensing receiver node may measure and report a set of angle-of-arrival (AoA) measurements corresponding to a group of observed paths detected (or associated with) the reflector object.

[0035] The NF region of a radio node may be interpreted as an area or collection of points which are closer than a specific radius/distance to the radio node. According to one definition, the NF region is the collection of points (e.g., spatial locations) for the placement of a second radio node such that the perceived AoA angle-of-arrival and/or AoD associated with the rays (i.e., propagation paths) initiated from the first radio node and terminated at the second radio node are not identical, or differ with at least a threshold of angle difference. Additionally, or alternatively, the NF region may be defined as the collection of points (e.g., spatial locations) for the placement of a second radio node, such that the received phase-difference at two antennas (of the second radio node) of a ray (i.e., propagation path) initiated from the first radio node and terminated at the second radio node is not linearly dependent on the distance between the two antennas of the second radio node.

[0036] Aspects of the present disclosure describe the communication and utilization of the additional information associated with the NF wavefront of a beam for the sensing and/or positioning of a target. In some aspects of the present disclosure, the sensing receiver node involved in the sensing operation may detect, measure and report a path group to an SensMF or another node involved in the sensing procedure. In certain aspects of the present disclosure, the report sent from the sensing receiver node may include a path group type and/or an NF condition of a reflector/object associated with a path group. In certain aspects of the present disclosure, the report sent from the sensing receiver node may include path group statistics measured by the sensing receiver node.

[0037] In some aspects of the present disclosure, the sensing receiver node may indicate that a first path group should be associated with a second path group and/or with an object identifier (ID). In some other aspects of the present disclosure, the SensMF may indicate (to the sensing receiver node) that a first path group should be associated with a second path group and/or with an object ID. In some aspects of the present disclosure, the SensMF may estimate the position of a sensing receiver node based on the reported path group measurements associated with a known reflector.

[0038] Beneficially, by measuring and reporting the path group information, the sensing receiver node improves the resolution of the sensing procedure, thereby improving the accuracy of positioning information derived from sensing measurements. Additionally, reporting path group information and other information associated with the NF beam pattern (e.g., spherical wavefront), the sensing receiver node enables the detection of distinct parts of the target object, such as head, torso, limbs, etc. of a human target object.

[0039] Aspects of the present disclosure are described in the context of a wireless communications system.

[0040] **Figure 1** illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a

Long-Term Evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a New Radio (NR) network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network.

[0041] In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology (RAT) including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0042] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0043] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0044] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an internet-of-things (IoT) device, an internet-of-everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0045] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0046] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0047] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or

interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0048] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or a PDN connection, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0049] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0050] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second

numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0051] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0052] Additionally, or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively.#

[0053] Each slot may include a number (e.g., quantity) of symbols (e.g., orthogonal frequency domain multiplexing (OFDM) symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0054] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0055] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0056] Wireless communication in unlicensed spectrum (also referred to as “shared spectrum”) in contrast to licensed spectrum offer some obvious cost advantages allowing communication to obviate overlaying operator’s licensed spectrum and rather use license free spectrum according to local regulation in specific geographies. From the third generation partnership project (3GPP) technology perspective, the unlicensed operation can be on the Uu interface (referred to as NR-U) or also on sidelink interface (e.g., SL-U).

[0057] For initial access, a UE 104 detects a candidate cell and performs downlink (DL) synchronization. For example, the gNB (e.g., an embodiment of the NE 102) may transmit a synchronization signal and physical broadcast channel (SS/PBCH) transmission, referred to as a synchronization signal block (SSB). In various embodiments, the SSB comprises the

primary synchronization signal (PSS), the secondary synchronization signal (SSS), and the master information block (MIB). The synchronization signal (i.e., comprising the PSS and SSS) is a predefined data sequence known to the UE 104 (or derivable using information already stored at the UE 104) and is in a predefined location in time relative to frame/subframe boundaries, etc. The UE 104 searches for the SSB and uses the SSB to obtain DL timing information (e.g., symbol timing) for the DL synchronization. The UE 104 may also decode system information (SI) based on the SSB. Note that with beam-based communication, each DL beam may be associated with a respective SSB.

[0058] After performing DL synchronization and acquiring essential system information, such as the MIB and the system information block type 1 (SIB1), the UE 104 performs uplink (UL) synchronization and resource request by performing a random-access procedure, referred to as "RACH procedure" by selecting and transmitting a preamble on the physical random access channel (PRACH). The PRACH preamble is transmitted during a random access channel (RACH) occasion, i.e., a predetermined set of time-frequency resources that are available for the reception of the PRACH preamble. Note that with beam-based communication, the UE 104 may select a certain DL beam and transmit the PRACH preamble on a corresponding UL beam. In such embodiments, there may be a mapping between SSB and RACH occasion, allowing the network to determine which beam the UE 104 has selected.

[0059] In 3GPP New Radio (NR), the gNB may transmit the maximum 64 SSBs and the maximum 64 corresponding copies of physical downlink control channel (PDCCH) and/or physical downlink shared channel (PDSCH) for delivery of SIB1 in high frequency bands (e.g., 28 GHz). This may cause significant network energy consumption even for a very low traffic load condition. According to 3GPP Technical Report (TR) 38.864 (v18.1.0), for network energy savings, on-demand SSB and/or SIB1 (SSB/SIB1) transmissions and a cell without SSB/SIB1 transmission were considered. When a cell does not transmit SSB/SIB1, for a UE 104 to access the cell, the UE 104 should obtain SI of the cell from other associated carriers/cells and synchronize from other associated carriers/cells. When a cell is in a long period of cell inactivity, a UE 104 served by the cell can trigger SSB/SIB1 transmissions by sending a request to the cell.

[0060] **Figure 2** illustrates an example of a protocol stack 200, in accordance with aspects of the present disclosure. While Figure 2 shows a UE 206, a RAN node 208, and a 5G core network (5GC) 210 (e.g., comprising at least an AMF), these are representative of a set of UEs 104 interacting with an NE 102 (e.g., base station) and a CN 106. As depicted, the protocol stack 200 comprises a user plane protocol stack 202 and a control plane protocol stack 204. The user plane protocol stack 202 includes a physical (PHY) layer 212, a medium access control (MAC) sublayer 214, a radio link control (RLC) sublayer 216, a packet data convergence protocol (PDCP) sublayer 218, and a service data adaptation protocol (SDAP) sublayer 220. The control plane protocol stack 204 includes a PHY layer 212, a MAC sublayer 214, a RLC sublayer 216, and a PDCP sublayer 218. The control plane protocol stack 204 also includes a radio resource control (RRC) layer 222 and a non-access stratum (NAS) layer 224.

[0061] The access stratum (AS) layer 226 (also referred to as "AS protocol stack") for the user plane protocol stack 202 consists of at least SDAP, PDCP, RLC and MAC sublayers, and the physical layer. The AS layer 228 for the control plane protocol stack 204 consists of at least RRC, PDCP, RLC and MAC sublayers, and the physical layer. The layer-1 (L1) includes the PHY layer 212. The layer-2 (L2) is split into the SDAP sublayer 220, PDCP sublayer 218, RLC sublayer 216, and MAC sublayer 214. The layer-3 (L3) includes the RRC layer 222 and the NAS layer 224 for the control plane and includes, e.g., an internet protocol (IP) layer and/or PDU Layer (not depicted) for the user plane. L1 and L2 are referred to as "lower layers," while L3 and above (e.g., transport layer, application layer) are referred to as "higher layers" or "upper layers."

[0062] The PHY layer 212 offers transport channels to the MAC sublayer 214. The PHY layer 212 may perform a beam failure detection procedure using energy detection thresholds, as described herein. In certain embodiments, the PHY layer 212 may send an indication of beam failure to a MAC entity at the MAC sublayer 214. The MAC sublayer 214 offers logical channels to the RLC sublayer 216. The RLC sublayer 216 offers RLC channels to the PDCP sublayer 218. The PDCP sublayer 218 offers radio bearers to the SDAP sublayer 220 and/or RRC layer 222. The SDAP sublayer 220 offers QoS flows to the core network (e.g., the 5GC 210). The RRC layer 222 provides for the addition, modification, and release of carrier aggregation and/or dual connectivity. The RRC layer 222 also manages the establishment,

configuration, maintenance, and release of signaling radio bearers (SRBs) and data radio bearers (DRBs).

[0063] The NAS layer 224 is between the UE 206 and an AMF in the 5GC 210. NAS messages are passed transparently through the RAN. The NAS layer 224 is used to manage the establishment of communication sessions and for maintaining continuous communications with the UE 206 as it moves between different cells of the RAN. In contrast, the AS layers 226 and 228 are between the UE 206 and the RAN (i.e., RAN node 208) and carry information over the wireless portion of the network. While not depicted in Figure 2, the IP layer exists above the NAS layer 224, a transport layer exists above the IP layer, and an application layer exists above the transport layer.

[0064] The MAC sublayer 214 is the lowest sublayer in the L2 architecture of the NR protocol stack. Its connection to the PHY layer 212 below is through transport channels, and the connection to the RLC sublayer 216 above is through logical channels. The MAC sublayer 214 therefore performs multiplexing and demultiplexing between logical channels and transport channels: the MAC sublayer 214 in the transmitting side constructs MAC PDUs (also known as transport blocks (TBs)) from MAC service data units (SDUs) received through logical channels, and the MAC sublayer 214 in the receiving side recovers MAC SDUs from MAC PDUs received through transport channels.

[0065] The MAC sublayer 214 provides a data transfer service for the RLC sublayer 216 through logical channels, which are either control logical channels which carry control data (e.g., RRC signaling) or traffic logical channels which carry user plane data. On the other hand, the data from the MAC sublayer 214 is exchanged with the PHY layer 212 through transport channels, which are classified as UL or downlink (DL). Data is multiplexed into transport channels depending on how it is transmitted over the air.

[0066] The PHY layer 212 is responsible for the actual transmission of data and control information via the air interface, i.e., the PHY layer 212 carries all information from the MAC transport channels over the air interface on the transmission side. Some of the important functions performed by the PHY layer 212 include coding and modulation, link adaptation (e.g., adaptive modulation and coding (AMC)), power control, cell search and random access

(for initial synchronization and handover purposes) and other measurements (inside the 3GPP system (i.e., NR and/or LTE system) and between systems) for the RRC layer 222. The PHY layer 212 performs transmissions based on transmission parameters, such as the modulation scheme, the coding rate (i.e., the modulation and coding scheme (MCS)), the number of physical resource blocks (PRBs), etc.

[0067] In some embodiments, the protocol stack 200 may be a NR protocol stack used in a 5G NR system. Note that an LTE protocol stack comprises similar structure to the protocol stack 200, with the differences that the LTE protocol stack lacks the SDAP sublayer 220 in the AS layer 226, that an EPC replaces the 5GC 210, and that the NAS layer 224 is between the UE 206 and an MME in the EPC. Also note that the present disclosure distinguishes between a protocol layer (such as the aforementioned PHY layer 212, MAC sublayer 214, RLC sublayer 216, PDCP sublayer 218, SDAP sublayer 220, RRC layer 222 and NAS layer 224) and a transmission layer in multiple-input multiple-output (MIMO) communication (also referred to as a "MIMO layer" or a "data stream").

[0068] The NF and FF refer to regions of the electromagnetic (EM) field around an object, such as a transmitting antenna, or the result of radiation scattering off an object. Non-radiative NF behaviors dominate close to the antenna or scatterer, while electromagnetic radiation FF behaviors predominate at greater distances.

[0069] **Figure 3** depicts an example of an electromagnetic signal 300 having an NF region 302, a transition zone 304, and an FF region 306 in accordance with aspects of the present disclosure. The boundary between the NF and FF regions is not constant across all antennas, as it depends on the dominant wavelength emitted by the source and the size of the radiating element.

[0070] The NF region 302 refers to places nearby the antenna conductors, or inside any polarizable media surrounding it, where the generation and emission of electromagnetic waves can be interfered with while the field lines remain electrically attached to the antenna. The electric and magnetic fields can exist independently of each other in the NF region 302, and one type of field can be disproportionately larger than the other, in different subregions.

[0071] The NF region 302 may be further defined into a reactive NF region and a radiative NF region. In the reactive NF region (nearest to the antenna), an interaction with the medium (e.g., body capacitance) can cause energy to deflect back to the source feeding the antenna. In the radiative NF region (further away from the antenna), an interaction with the medium can fail to return energy back to the source, but cause a distortion in the electromagnetic wave that deviates significantly from that found in free space.

[0072] The transition zone 304 can either be considered the furthest part of the NF region 302, or the nearest part of the FF region 306. The transition zone 304 may be defined based on antenna geometry and excitation wavelength. In some embodiments, the transition zone 304 is approximately one wavelength from the antenna. The electric and magnetic parts of the radiated waves first balance out in the transition zone 304. In one example, the electric field of a linear antenna gains its corresponding magnetic field in the transition zone 304. In another example, the magnetic field of a loop antenna gains its electric field in the transition zone 304.

[0073] In contrast, the FF region 306 is the region in which the field has settled into "normal" electromagnetic radiation. The FF region 306 is dominated by transverse electric or magnetic fields with electric dipole characteristics. In the FF region of an antenna, radiated power decreases as the square of distance, and absorption of the radiation does not feed back to the transmitter. In some embodiments, the FF region 306 begins approximately two wavelengths from the antenna and extends to infinity.

[0074] To improve the sensing procedure, the present disclosure describes techniques and procedures for performing a sensing procedure based at least in part on an NF wavefront or an NF radiation pattern of one or more sensing signals.

[0075] Regarding network-based and UE-based (i.e., SL-based) radio sensing operations, different scenarios for radio sensing are presented in Figures 4A and 4B. In some scenarios of radio sensing, the network configures the participating sensing entities, i.e., network and UE nodes acting as sensing transmitter nodes, network and UE nodes acting as sensing receiver nodes, as well as the configuration of sensing RS and necessary measurements and reporting procedures from the nodes. In this regard, the functional split between the network

and the UE nodes for a specific sensing task may take various forms, depending on the availability of sensing-capable devices and the requirements of the specific sensing operation.

[0076] **Figure 4A** depicts possibilities for sensing scenarios for a radio sensing operation 400 where a RAN entity performs a sensing RS transmission, according to embodiments of the disclosure. In the scenarios of Figure 4A, sensing RS reception is performed by one or more UEs, one or more RAN entities, or a combination thereof. The radio sensing operation 400 may involve a first RAN entity 402 (e.g., a gNB or network TRP node), a second RAN entity 404 (e.g., a gNB or a network TRP node), and/or a set of at least one UE (represented by the first UE 406).

[0077] In various embodiments, the radio sensing operation 400 is used to detect and locate an object of interest 408. In general, a Radio-based sensing transmission 410 is performed by the first RAN entity 402. While the below examples describe the Radio-based sensing transmission 410 using a sensing reference signal ("sensing RS") 412, in other embodiments the Radio-based sensing transmission 410 may be a transmission of another RS or instead may be a transmission of the data/control channels known to the network TRP nodes.

[0078] In a first sensing scenario (also referred to herein as "Case I"), the Radio-based sensing transmission 410 is performed by a first network node (i.e., the first RAN entity 402) and the Radio-based sensing reception 416 is performed by a separate network node (i.e., the second RAN entity 404). In this case, the sensing RS 412 (or another RS used for sensing) is transmitted and a reflection/backscatter signal 414 is received by network entities. The network does not utilize UEs for sensing assistance in this scenario. Rather, the involvement of UE nodes (i.e., first UE 406) is limited to the aspects of interference management, when necessary.

[0079] In a second sensing scenario (also referred to herein as "Case II"), the Radio-based sensing transmission 410 is performed by a first network node (i.e., the first RAN entity 402) and the Radio-based sensing reception 418 is performed by the same network node. In this case, the sensing RS 412 (or another RS used for sensing) is transmitted and a

reflection/backscatter signal 414 is received by the same network entity. The network does not utilize UEs for sensing assistance in this scenario. Rather, the involvement of UE nodes (i.e., first UE 406) is limited to the aspects of interference management, when necessary.

[0080] In a third sensing scenario (also referred to herein as "Case III"), the Radio-based sensing transmission 410 is performed by a first network node (i.e., the first RAN entity 402) and the Radio-based sensing reception 420 is performed by a UE node (i.e., the first UE 406). In this case, the sensing RS 412 (or other RS used for sensing) is transmitted by a network entity and a reflection/backscatter signal 414 is received by one or multiple UE nodes, including the first UE 406. The network configures the UEs to act as a sensing receiver node, according to the UE capabilities for sensing, as well as desired sensing task.

[0081] **Figure 4B** depicts possibilities for sensing scenarios for a radio sensing operation 430 where a UE performs a sensing RS transmission, according to embodiments of the disclosure. In the scenarios of Figure 4B, sensing RS reception is performed by one or more UEs, one or more RAN entities, or a combination thereof. The radio sensing operation 430 may involve the first UE 406, a set of at least one peer UE (represented by the second UE 432), and/or a set of at least one TRP (represented by the first RAN entity 402).

[0082] In various embodiments, the radio sensing operation 430 is used to detect and locate an object of interest 408. In general, a Radio-based sensing transmission 434 is performed by the first UE 406. While the below examples describe the Radio-based sensing transmission 434 using a sensing RS 436, in other embodiments the Radio-based sensing transmission 434 may be a transmission of another RS or instead may be a transmission of the data/control channels.

[0083] In a fourth sensing scenario (also referred to herein as "Case IV"), the Radio-based sensing transmission 434 is performed by a first UE 406 and the Radio-based sensing reception 440 is performed by a RAN entity (i.e., the first RAN entity 402). In this case, the sensing RS 436 (or another RS transmitted for sensing) is transmitted by a UE node and a reflection/backscatter signal 438 is received by one or multiple network entities. The network configures the transmitting UE (i.e., the first UE 406) to act as a sensing transmitter node,

according to the UE nodes' capabilities for sensing, as well as the nature of the desired sensing task.

[0084] In a fifth sensing scenario (also referred to herein as "Case V"), the Radio-based sensing transmission 434 is performed by a first UE 406 and the Radio-based sensing reception 442 is performed by a separate UE (i.e., the second UE 432). In this case, the sensing RS 436 (or another RS transmitted for sensing) is transmitted by a UE node and a reflection/backscatter signal 438 is received by one or multiple UE nodes. The network, or potentially the first UE 406, may decide on configuration of the sensing scenario. In one instance, the network configures the UEs to act as a sensing transmitter node and/or sensing receiver nodes, according to the UE nodes capabilities for sensing, as well as the nature of the desired sensing task.

[0085] In a sixth sensing scenario (also referred to herein as "Case VI"), the Radio-based sensing transmission 434 is performed by a first UE 406 and the Radio-based sensing reception 444 is performed by the same UE. In this case, the sensing RS 436 (or another RS transmitted for sensing) is transmitted by a UE node and a reflection/backscatter signal 438 is received by the same UE node. The UE or the network configures the sensing scenario, according to the UE nodes capabilities for sensing, as well as the nature of the desired sensing task.

[0086] The above radio sensing scenarios are described in further detail in U.S. Application 17/538,978 entitled "CONFIGURING A SENSING REFERENCE SIGNAL" and filed on November 30, 2021 for Seyedomid Taghizadeh Motlagh, Ali Ramadan Ali, Ankit Bhamri, Sher Ali Cheema, Razvan-Andrei Stoica, Hyejung Jung and Vijay Nangia, and also described in further detail in U.S. Application 17/538,998 entitled "SENSING REFERENCE SIGNAL CONFIGURATION" and filed on November 30, 2021 for Seyedomid Taghizadeh Motlagh, Ali Ramadan Ali, Ankit Bhamri, Sher Ali Cheema, Razvan-Andrei Stoica, Hyejung Jung and Vijay Nangia, which applications are incorporated herein by reference.

[0087] Moreover, the above scenarios are not intended to be restricted to a specific UE type, and may include any UE category. In any of the above scenarios, and of the roles

elaborated for gNB and/or UE may be replaced (with equal validity for any example of a radio sensing scenario) with any UE or RAN node, e.g., a smart repeater node, an Integrated Access and Backhaul (IAB) node, a roadside unit (RSU), etc. In some examples, the set of sensing transmitter nodes of a sensing measurement process (and similarly, but may be independently, a sensing receiver nodes of a sensing measurement process) include one or more of a TRP associated with a gNB-CU/DU, a gNB distributed unit (gNB-DU), a gNB control unit (gNB-CU), a UE, a network controlled repeater (NCR), an IAB node, an RSU, or a dedicated sensing radio. In some embodiments, a sensing receiver node may as well be a non-3GPP sensor with capability of providing non-3GPP sensing data, or a 3GPP node (e.g., a UE or a RAN node) connected to the non-3GPP sensor and can obtain, process, and transfer the non-3GPP sensing data of the non-3GPP sensor to other 3GPP nodes/entities.

[0088] Integrated sensing and communication may enhance 5G core architecture by introducing a new Sensing Function (SF). Figures 5A-5D present possible combinations leading to the network impact.

[0089] **Figure 5A** illustrates an example of a tight coupling ISAC network architecture 500 with a unified SF (i.e., where the SF is not split between the control plane (CP) and user plane (UP) domains. As depicted, the SF is communicatively coupled to the Access and Mobility management Function (AMF), the Unified Data Management node (UDM), the Network Data Analytics Function (NWDAF), the Location Management Function (LMF), the Policy Control Function (PCF), the Network Exposure Function (NEF), and to the (radio) access network ((R)AN), optionally via the User Plane Function (UPF).

[0090] In the tight coupling ISAC network architecture 500, the SF appears as a dedicated network function handling both: *i*) the sensing control plane aspects such as the interaction with the sensing consumer via NEF and information exchange with other network functions, for gathering UE information, (i.e., from the AMF, the UDM, the LMF), for gathering UE related policies from the PCF, and for gathering analytics from the NWDAF; and *ii*) the sensing radio signals for performing the analysis or prediction for determining the sensing target.

[0091] **Figure 5B** illustrates another example of a tight coupling ISAC network architecture 510, where the SF is functionally split/distributed among the CP and UP domains. As depicted, a CP split of the SF (SF-C) is communicatively coupled to the AMF, the UDM, the NWDAF, the LMF, the PCF, and the NEF. Additionally, a UP split of the SF (SF-C) is communicatively coupled to the (R)AN, optionally via the UPF.

[0092] In the tight coupling ISAC network architecture 510 with CP/UP split, the SF has two dedicated network function counter parts: *i*) SF-C that handles the control plane aspects as described above and *ii*) SF-U that is responsible for collecting the sensing radio signals via the user plane, i.e., via the (R)AN and the UPF. The idea of this architecture is to split and offload heavy data volumes associated with sensing radio signals to the user plane to ensure light traffic, i.e., only signaling, in the control plane.

[0093] **Figure 5C** illustrates an example of an ISAC network architecture 520, where the SF is co-located with the LMF. The SF is communicatively coupled with the LMF, where the co-located nodes are also coupled with the Gateway Mobile Location Center (GMLC) and the AMF. As depicted, the GMLC is additionally coupled with the UDM, the AMF and the NEF. The AMF is additionally coupled with the UDM, the NEF, the (R)AN, and the UE. The NEF is additionally coupled with the application function (AF). The (R)AN is additionally coupled with the UE. The inter-function interfaces (i.e., reference points) are labeled in Figure 5C. In the ISAC network architecture 520, the SF (i.e., co-located with the LMF) appears as a logical network function embedded in the LMF to perform sensing taking advantage of the knowledge of a UE location.

[0094] **Figure 5D** illustrates an example of a loose coupling ISAC network architecture 530, where the SF is communicatively coupled with the (R)AN and with the AF, optionally via the NEF. The SF may optionally be coupled with one or more of: the AMF (directly or via the (R)AN), the NWDAF, the NEF, and the UE (via the (R)AN). The inter-function interfaces (i.e., reference points) are labeled in Figure 5C.

[0095] In the loose coupling ISAC network architecture 530, the SF is independent of the 5G core, i.e., typically used for local field scenarios or private networks, and the interaction with the 5G core is minimal. The main idea is to use SF close to the RAN, i.e., collect and

process the sensing radio signals locally, and interact with 5G core for the purpose of exposure via NEF, for getting the UE location from the AMF and for analytics (i.e., NWDAF interaction).

[0096] In another description of controlling a sensing operation, in some example implementations, a sensing controller entity/function (SensMF) is defined which comprises one or multiple of a UE, a RAN node, a gNB/gNB-CU, an LMF, an SF, or a combination thereof, wherein the SensMF performs one or multiple of: A) Receives request for sensing information from a service consumer (e.g., a requesting third party application); B) Determines selection and/or configuration of a sensing operation, including configuration of one or more of a sensing transmitter node, sensing receiver node; C) Selects and/or configures the involved nodes for sensing transmission and sensing reception and sensing measurement and reporting of the conducted measurements; D) Collects the sensing measurements; E) Performs or configures or requests computation of the sensing measurements and thereby determines the required sensing information based on the obtained sensing measurements; and/or F) Reports/exposes an obtained sensing information to the entity requesting the sensing information.

[0097] In some examples wherein the SensMF is comprised of multiple nodes/entities, one part of the above-mentioned steps may be implemented by the first part of the SensMF, and the second part of the above steps may be implemented by the second part of the SensMF, e.g., implemented in the SF and gNB. In some examples wherein the SensMF is comprised of multiple nodes/entities, the communication among the SensMF entities is transparent to the outside entities and also not discussed in the related handover procedure embodiments, nevertheless, the communication among the SensMF entities is assumed to be implicit to the overall procedure.

[0098] In some examples, wherein a SensMF is comprised of an SF and a gNB (e.g., serving/head gNB of a related UE to the sensing task or a selected serving gNB for a sensing task), the SF performs the steps A, F, E, D whereas the steps B, C are performed by the selected gNB node. In some other examples, the step B, D are jointly performed by the SF and the selected gNB, wherein a first part of the configuration/configuration determination are performed by the SF and a second part of the configuration/configuration determination

is performed by the selected gNB. The SensMF may be a RAN node (e.g., a selected gNB node acting as serving gNB of a sensing task), may be a sensing function (SF) residing in core network, may be a UE, or a combination thereof.

[0099] The following L1 measurements are relevant to sensing operation in accordance with the present disclosure: UE receiver-to-transmitter (Rx-Tx) time difference; gNB Rx-Tx time difference, DL PRS reference signal received path power (RSRPP), UL SRS RSRPP.

[0100] The UE Rx-Tx time difference is defined as $T_{UE\text{-}RX} - T_{UE\text{-}TX}$, where $T_{UE\text{-}RX}$ is the UE receive timing of downlink subframe #*i* from a Transmission Point (TP), defined by the first detected path in time, and where $T_{UE\text{-}TX}$ is the UE transmit timing of uplink subframe #*j* that is closest in time to the subframe #*i* received from the TP. Note that multiple DL PRS or CSI-RS for tracking resources, as instructed by higher layers, can be used to determine the start of one subframe of the first arrival path of the TP.

[0101] For frequency range #1 (FR1), the reference point for $T_{UE\text{-}RX}$ measurement is the receiver antenna connector of the UE and the reference point for $T_{UE\text{-}TX}$ measurement is the transmitter antenna connector of the UE. For frequency range #2 (FR2), the reference point for $T_{UE\text{-}RX}$ measurement is the receiver antenna of the UE and the reference point for $T_{UE\text{-}TX}$ measurement is the transmitter antenna of the UE. The UE Rx-Tx time difference is applicable to a UE in the RRC_CONNECTED state and in the RRC_INACTIVE state.

[0102] The gNB Rx-Tx time difference is defined as $T_{gNB\text{-}RX} - T_{gNB\text{-}TX}$, where $T_{gNB\text{-}RX}$ is the Transmission and Reception Point (TRP) received timing of uplink subframe #*i* containing SRS associated with UE, defined by the first detected path in time, and where $T_{gNB\text{-}TX}$ is the TRP transmit timing of downlink subframe #*j* that is closest in time to the subframe #*i* received from the UE. Multiple SRS resources can be used to determine the start of one subframe containing SRS.

[0103] The reference point for the $T_{gNB\text{-}RX}$ shall be: the receiver antenna connector for a type 1-C base station (e.g., as described in 3GPP technical specification (TS) 38.104); the receiver antenna (i.e., the center location of the radiating region of the receiver antenna) for a type 1-O or 2-O base station (e.g., as described in 3GPP TS 38.104), or the receiver

Transceiver Array Boundary connector for a type 1-H base station (e.g., as described in 3GPP TS 38.104).

[0104] Similarly, the reference point for the $T_{gNB\text{-}TX}$ shall be: the transmitter antenna connector for a type 1-C base station (e.g., as described in 3GPP TS 38.104); the transmitter antenna (i.e., the center location of the radiating region of the transmitter antenna) for a type 1-O or 2-O base station (e.g., as described in 3GPP TS 38.104), or the transmitter Transceiver Array Boundary connector for a type 1-H base station (e.g., as described in 3GPP TS 38.104).

[0105] The DL PRS-RSRPP is defined as the power of the linear average of the channel response at the *i*-th path delay of the resource elements that carry DL PRS signal configured for the measurement, where DL PRS-RSRPP for the 1st path delay is the power contribution corresponding to the first detected path in time.

[0106] For FR1, the reference point for the DL PRS-RSRPP shall be the antenna connector of the UE. For FR2, DL PRS-RSRPP shall be measured based on the combined signal from antenna elements corresponding to a given receiver branch. The UE Rx-Tx time difference is applicable to a UE in the RRC_CONNECTED state and in the RRC_INACTIVE state.

[0107] The UL SRS-RSRPP is defined as the power of the linear average of the channel response at the *i*-th path delay of the resource elements that carry the received UL SRS signal configured for the measurement, where UL SRS-RSRPP for 1st path delay is the power contribution corresponding to the first detected path in time.

[0108] The reference point for UL SRS-RSRPP shall be: the receiver antenna connector for a type 1-C base station (e.g., as described in 3GPP TS 38.104); based on the combined signal from antenna elements corresponding to a given receiver branch for a type 1-O or 2-O base station (e.g., as described in 3GPP TS 38.104), or the receiver Transceiver Array Boundary connector for a type 1-H base station (e.g., as described in 3GPP TS 38.104).

[0109] For FR1 and FR2, if receiver diversity is in use by the gNB for UL SRS-RSRPP measurements, then: 1) the reported UL SRS-RSRPP value for the first and additional paths shall be provided for the same receiver branch(es) as applied for UL SRS reference signal

received power (SRS-RSRP) measurements; or 2) the reported UL SRS-RSRPP value for the first path shall not be lower than the corresponding UL SRS-RSRPP for the first path of any of the individual receiver branches and the reported UL SRS-RSRPP for the additional paths shall be provided for the same receiver branch(es) as applied UL SRS-RSRPP for the first path.

[0110] In some use-cases of sensing, it is of interest to perform sensing measurement and reporting at a sensing receiver node located at an NF of a reflector object. The close reflector-to-receiver node distance leads to better observability (e.g., received energy), and better capability of the sensing receiver node to observe and distinguish rays reflected from object parts. In such situations, when the sensing receiver node is capable of a high resolution temporal (e.g., large bandwidth) and angular (e.g., large antenna/array aperture) measurement the sensing receiver node may be configured to measure and report signaling path properties of a group of distinct paths (or rays or MPCs), e.g., AoA of group of observed paths detected/associated in relation to a reflector object.

[0111] **Figure 6** depicts a chart 600 of the observed channel response for a sensing procedure involving a human target object as a reflector object, in accordance with aspects of the present disclosure. Here, it is assumed that the human target object has dimensions of approximately 170 cm × 30 cm × 20 cm. The observed channel response considers an NF scenario, with a TRP-to-TRP distance of 20 meters. The channel may comprise a plurality of distinct time samples, AoA and/or zenith-of-arrival (ZoA) values, depending on the receiver beam/bandwidth and processing capability.

[0112] As depicted in Figure 6, multiple channel delay samples are observable associated with the human target object. As such, depending on the target size/shape, receiver (i.e., sensing receiver node) location, as well as the receiver processing capability of bandwidth and beamwidth/resolution, the associated channel to the human target object can be observed as a group of paths and not a single path. As such, this necessitates a reporting mechanism to inform a sensing/positioning management entity of the observed path group associated with a target object.

[0113] As one solution, each path (or ray or MPC) of the path group can be separately reported to the SensMF. According to this solution, the SensMF analyzes the reported paths (or rays or MPCs) and may determine that a path group exists. However, this approach can be inefficient and may result in increased reporting overhead. Therefore, the above solution may be enhanced by the pre-processing of the path group at the measurement node (i.e., sensing receiver node). The enhanced solution has the advantage of both reducing the reporting overhead and leveraging locally available data at the measurement node (when applicable) for initial processing of the path group.

[0114] While the current 3GPP channel model describes modelling of path/ray clusters with different delay, AoA/ZoA of rays within a cluster, the current 3GPP measurement framework does not support reporting of a group of rays (i.e., a path group) associated with a detected cluster which share one or more signal properties, but may be different in one or more of their delay, doppler shift, AoA, ZoA, etc.

[0115] Accordingly, the following solutions describe techniques to facilitate the exchange of necessary information for the measurement and/or reporting of a sensing signal reflection from a reflector object when the measurement node (i.e., sensing receiver node) is located at the NF of the reflector object and/or other scenarios when the sensing signal reflection is distinguishable at the measurement node via a plurality of reflected path/rays.

[0116] A SensMF derives sensing results of a sensing task (e.g., of detecting an intruder in a smart home) based on at least a measurement report of a sensing receiver node from a sensing signal transmission of a sensing transmitter node. In various embodiments, the sensing results are derived based on an NF beam pattern resulting from spherical wavefront for the reflection of the sensing signal, the location of the sensing transmitter node, the location of the sensing receiver node, and the location of the reflection point, wherein the sensing signal is transmitted by the sensing transmitter node and reflected by a reflector, such as the target object.

[0117] Moreover, the sensing receiver node may leverage locally available data for initial processing of a path group associated with the target object and reflected sensing signal(s). Accordingly, the sensing receiver node may transmit (to the SensMF) a report indicating a

path group and, optionally, a path group type (e.g., including a group of an NF reflector), with respect to the envisioned spread of delay, doppler, azimuth, elevation as observed by the sensing receiver node. Still further, the SensMF may configure the sensing receiver node with reporting quantities and/or reporting procedures for reporting path group properties, as described in the following solutions.

[0118] It is understood that the present disclosure is not limited to the single embodiment and/or implementation elements individually, and one or more elements from one or more implementations and/or embodiments may be combined to construct a new embodiment. Moreover, applicability/utilization of any of the proposed message exchange, architecture, configuration, measurement, capability information elements within this disclosure is not intended to be restricted to the particularly defined scenario and is intended to be interpreted as applicable for any alternate application/scenario, e.g., not being limited to a sensing measurement scenario and/or a positioning measurement scenario.

[0119] It is understood that this disclosure is not limited to any single embodiment and/or implementation of elements individually, and that one or more elements from one or more implementations and/or embodiments may be combined to construct a new embodiment. Moreover, the applicability/utilization of any of the proposed message exchange, architecture, configuration (e.g., of a measurement), measurement, and/or capability information elements within this disclosure is not intended to be restricted to the particularly defined scenario and is intended to be interpreted as applicable for any alternate application/scenario (e.g., not being limited to the sensing measurement scenarios and/or the positioning measurement scenarios described within the present disclosure). For example, any measurement/configuration step applicable for a path group, may as well be applied to a path, to a path cluster/subgroup, or to a group of path groups.

[0120] Moreover, the following terminologies may be used interchangeably within this disclosure, describing a shared concept: group of paths, path group, channel associated with a group of propagation paths, channel associated with a reflector object (e.g., for the propagation paths (or rays or MPCs) initiated at a transmission node and terminated at a reception node).

[0121] In accordance with aspects of a first solution, a radio node (e.g., UE or NE) is configured to perform a reception of a reflected signal (e.g., of an impinging signal transmitted by a second radio node), according to an incoming (e.g., reception, impinging) beam/radiation pattern. In some embodiments, the second node (i.e., transmitting the impinging signal) may be a reconfigurable intelligent surface (RIS) that reflects the impinging signal, or an NCR that re-transmits a received signal.

[0122] More particularly, a sensing receiver node, as part of a sensing measurement and reporting configuration, receives a configuration for the detection of a path group and the sensing measurement(s) to be performed in a sensing procedure to obtain parameters of the path group. Responsive to reception of the sensing measurement and reporting configuration, the sensing receiver node performs at least one or more of: detecting a path group, measuring the sensing signal(s) to obtain parameters of a path group, and/or reporting the detection/presence and/or measured parameters of the path group. Based on one or more received sensing signals associated with the sensing procedure, the sensing receiver node generates a report based on the obtained measurement(s) and/or the detection of the path group, wherein the path group is associated with a reflector object. As used herein, a path group comprises a plurality of paths, or rays, or MPCs which differ in at least one path parameter.

[0123] According to some aspects of the first solution, a sensing receiver node is configured by the SensMF to perform sensing measurement and reporting, wherein the configuration of the sensing measurement and reporting may include one or more of:

[0124] A) an indication and/or configuration of parameters related to a sensing signal transmitted from a sensing transmitter node and to be received by the sensing receiver node; B) an indication and/or configuration of parameters and/or assistance information for detection and/or reporting of a path group; and/or C) an indication and/or configuration of parameters and/or assistance information for measurement/reporting of the one or multiple detected path groups.

[0125] In certain embodiments, the indication and/or configuration of these parameters may include definitions of a reference signal (RS) and/or a physical data or control channel

to be received at the sensing receiver node. The physical data/control channel may be an UL physical channel (e.g., physical uplink shared channel (PUSCH) or physical uplink control channel (PUCCH)), a DL physical channel (e.g., physical downlink shared channel (PDSCH) or physical downlink control channel (PDCCH)), or a SL physical channel (e.g., physical sidelink shared channel (PSSCH) or physical sidelink control channel (PSCCH)), while the RS may be a DL RS, a SL RS, a UL RS, and/or a TRP-to-TRP (TRP2TRP) RS. As such, the indication/configuration of the parameters related to an RS may include a SL/DL PRS ID, parameters/ID of a sensing dedicated RS, etc.

[0126] In certain embodiments, a path group comprising plurality of MPCs, rays, paths, or path (or ray or MPC) clusters, (e.g., as defined in 3GPP technical report (TR) 38.901) or a combination thereof, initiated from the sensing transmitter node and terminated at the sensing receiver node, and, in some examples, reflected by/associated with a common reflector object/entity (e.g., a sensing target object).

[0127] A path group may comprise a single group of paths (or rays or MPCs), or further grouped into multiple path groups, multiple subgroup of paths (or rays or MPCs). For example, the path group may comprise paths/rays initiated from the sensing transmitter, reflected from different points of a reflector object (e.g., a human body, a reflector indicated via a reflector/object ID) towards the sensing receiver node. As another example, the path group may comprise a broad path group corresponding to the reflection of a reflector object, and also subgroups of the path group comprising paths/ray clusters associated with (different parts of) the reflector object.

[0128] In certain embodiments, the indication and/or configuration for parameters and/or assistance information for measurement/reporting of the one or multiple detected path groups may include an indication of a measurement/reporting quantity to be generated individually from each path (or ray or MPC) of the path group or jointly from the plurality of paths (or rays or MPCs) of the path group.

[0129] In certain embodiments, the indication and/or configuration for parameters and/or assistance information for measurement/reporting of the one or multiple detected path groups may include an indication of time/frequency resources for reporting of a measured quantity,

occasion for reporting of a detected path/path group, or reporting of an event/feature associated with a path group.

[0130] As such, responsive to the sensing receiver node receiving the sensing measurement and reporting configuration and reception of the sensing signal, the sensing receiver node performs the configured measurement, generates the configured report, and transmits the configured report to the SensMF.

[0131] Figures 7-9 depict sensing scenarios for various embodiments of path group reporting for a group of paths/rays reflected from a human target by a sensing receiver node, in accordance with aspects of the present disclosure. In some implementations, a sensing receiver node is configured to perform measurement at an indicated area for sensing (e.g., detection, tracking, positioning, orientation/heading estimation, gesture recognition or a combination thereof) of a human target. Examples of a human target in a sensing operation include a pedestrian walking on a road segment to be monitored, or a human to be monitored for its condition/gestures in an indoor environment.

[0132] **Figure 7** depicts a sensing scenario 700 wherein a sensing transmitter node 702 transmits a set of one or more sensing signals corresponding to multiple transmitter propagation paths 704. The one or more sensing signals are reflected by a target object 706 (here, a human target). A sensing receiver node 708 receives and measures the one or more reflections corresponding to multiple reflection propagation paths 710.

[0133] The paths (or rays or MPCs) observed at the sensing receiver from the human sensing target are detected/reported as a path group to the SensMF 712. In the depicted embodiment, the sensing receiver node 708 groups the reflections from the (human) target object 706 into multiple path/ray groups wherein each path group is measured/reported separately by the sensing receiver node 708 (referred to herein as “Case A”). Here, the reported path groups include a first path group 714, a second path group 716, and an Nth path group 718.

[0134] **Figure 8** depicts a sensing scenario 800 wherein a sensing transmitter node 802 transmits a set of one or more sensing signals corresponding to multiple transmitter propagation paths 804. The one or more sensing signals are reflected by a target object 806

(here, a human target). A sensing receiver node 808 receives and measures the one or more reflections corresponding to multiple reflection propagation paths 810.

[0135] The paths (or rays or MPCs) observed at the sensing receiver from the human sensing target are detected/reported as a path group to the SensMF 812. In the depicted embodiment, the sensing receiver node 808 reports the observed path group 814 comprising the paths/rays reflected from the (human) target object 806, wherein the reflection from the human target is considered as a single path group (referred to herein as "Case B").

[0136] **Figure 9** depicts a sensing scenario 900 wherein a sensing transmitter node 902 transmits a set of one or more sensing signals corresponding to multiple transmitter propagation paths 904. The one or more sensing signals are reflected by a target object 906 (here, a human target). A sensing receiver node 908 receives and measures the one or more reflections corresponding to multiple reflection propagation paths 910.

[0137] The paths (or rays or MPCs) observed at the sensing receiver from the human sensing target are detected/reported as a path group to the SensMF 912. In the depicted embodiment, the sensing receiver node 908 groups the reflected paths from the (human) target object 906 as a path group by the sensing receiver node 908, and wherein the paths (or rays or MPCs) of the path group are further grouped into one or multiple subgroups by the sensing receiver node 908 (referred to herein as "Case C"), wherein as an example the paths (or rays or MPCs) associated with different body parts are further grouped into multiple subgroups. Here, the reported path groups include a first path group 914, a first subgroup 916, a second subgroup 918, and an Nth subgroup 920.

[0138] In some embodiments, detection of a path group and/or grouping of detected paths into the path groups at the sensing receiver node is done according to a criterion and/or a signaling path property associated with the path group. Examples of relevant criteria and/or signaling path properties include, but are not limited to: 1) a permissible or expected parameter range of the potential paths (or rays or MPCs); 2) a consistency of the paths (or rays or MPCs) associated with a path group; 3) an association with a previously detected path, path group, and/or object; or the like.

[0139] Regarding the permissible or expected parameter range of the potential paths/rays/multi-path components associated with the path group to be detected by the sensing receiver node, the parameter range may include one or more of: A) a time-of-arrival (ToA) and/or time-of-flight (ToF) range (e.g., [5-15 nsec] after a known time reference at the sensing receiver node), B) AoA range (e.g., [10-15 degrees] in AoA with respect to a global, local, or known coordinate system or known ZoA reference (e.g., of a previously detected path (and/or measured path), such as a line-of-sight (LOS) reception) at the sensing receiver node), C) a ZoA range (e.g., [10-15 degrees] in AoA with respect to a global, local, or known coordinate system or known ZoA reference (e.g., of a previously detected path (and/or measured path), such as a LOS reception) at the sensing receiver node), D) a doppler shift range (e.g., doppler shift of [0 Hz - 100 Hz]); E) an area of interest at which a reflector object may be located; F) a permissible velocity range of a reflector object; G) a joint/combined range (i.e., a range jointly defined in two or more of the above parameters); or any combination thereof.

[0140] Regarding the area of interest at which a reflector object may be located, in certain embodiments, upon indication of the area of interest, the sensing receiver node may determine a range of permissible AoA/ZoA, ToA/ToF values based on the indicated area of interest and its local coordinate system. Regarding the permissible velocity range of a reflector object, in certain embodiments, upon indication of the velocity range, the sensing receiver node may determine a range of doppler shift values based on the potential object/reflector area, a known coordinate system at the sensing receiver node etc.

[0141] Regarding the joint/combined range, in some embodiments, any path with AoA, ZoA, ToA, channel/carrier phase (corresponding to the channel response of a path), doppler shift values with no more than an indicated Euclidian distance (or weighted distance for which each parameter is multiplied with a corresponding indicated weight) of the AoA, ZoA, ToA, doppler shift value towards (AoA=10 degrees, ZoA = 15 degrees, ToA = 10 nsec, doppler shift = 100 Hz) according to known time/frequency/angular references at the sensing receiver node.

[0142] Regarding the consistency of the paths (or rays or MPCs) associated with a path group in their one or more properties of the path, in certain embodiments, the consistency

may be defined according to known time/frequency/angular references at the sensing receiver node, e.g., one or more of ToA/ToF, doppler shift, AoA, ZoA channel/carrier phase (corresponding to the channel response of a path). In certain embodiments, the consistency may be defined as a condition that the AoA of two paths belonging to a path group may not differ more than an indicated difference. In further embodiments, the consistency may be defined as a condition that a weighted sum (e.g., weights of w-ToA = 0.1, w-AoA = 0.2, w-ZoA = 0.3, etc.) of the differences of the path AoA, ZoA, doppler shift, ToA of two paths within the path group may not exceed an indicated threshold.

[0143] In certain embodiments, the consistency may be defined as the absolute RSRPP or the relative RSRPP of a path (e.g., as condition for inclusion in a grouping or a path group) or of a path group (as condition for detection of a path group) greater than a threshold.

[0144] In one example, to be considered as a path group, the consistency of the associated paths may require that the measured RSRPP of the path/path group be larger than an indicated (e.g., absolute) threshold, or above an indicated portion of the received power from an overall detected path group, or greater than an indicated portion of the path of the path group with maximum power. Alternatively, to satisfy the consistency requirement the measured RSRPP of a path/path group may need to exceed a previous RSRPP measurement of the path/path group by at least an indicated (e.g., relative) amount.

[0145] In another example, to be considered as a path group, the consistency of the associated paths may require that the summed RSRPP of the path/path group is larger than an indicated (e.g., absolute) threshold, or above an indicated portion of the received power from an overall detected path group, or greater than an indicated portion of the path of the path group with maximum power. Alternatively, to satisfy the consistency requirement the summed RSRPP of a path/path group may need to exceed a previous RSRPP measurement of the path/path group by at least an indicated (e.g., relative) amount.

[0146] Regarding the association with a previously detected path, a path group, or object, note that the previously detected path group may be defined using a path ID, a path group ID, and/or a path subgroup ID. Moreover, the indication of previously detected path group may be combined with an indication of the transmitted sensing signal (e.g., a sensing signal ID)

based on which the path/path group ID was previously measured. Also note that the previously detected object may be defined using an object ID and/or an object type.

[0147] In some embodiments, the association with a previously detected path, a path group, or object may be signaled in the case of the tracking/ monitoring of an object and, hence, the tracking/ monitoring the path group (e.g., with moving/changing path parameters) associated with the object over time.

[0148] In some embodiments, the association with a previously detected path, a previously detected path group, or object may be signaled in the case of the detection of a path which has been previously detected but later blocked (e.g., suffered an RSRPP drop), hence detection of the path/path group corresponds to a reference signal received power (RSRP) value, or RSRPP value (i.e., of the sensing signal), or summed RSRPP (sum-RSRPP) value of the previously detected path group being above a known (e.g., pre-configured) absolute threshold, or a relative threshold (i.e., where the current power measurement exceeds a previously measured RSRP/RSRPP/sum-RSRPP value of the path/path group by at least a threshold amount).

[0149] In some embodiments, the measurements (at the sensing receiver node) and/or reporting (by the sensing receiver node to the SensMF/network) of the path group include one or more of: A) a path group type associated with a detected/reported path group; B) an indication that a first path group is associated with a second path group; C) signaling path parameters and/or information of the path group; D) statistics associated with the signaling path parameters; E) differential measurements; F) a processing type used to identify the path group; G) the number of path subgroups within a path group; or any combination thereof.

[0150] Regarding the path group type, in various embodiments, the sensing receiver node determines a path group type associated with a detected/reported path group, and indicates (e.g., reports) the same to the SensMF. For example, the determined path group type may be based on a determination that the sensing receiver node is located in the NF of the object/reflector associated with the path group.

[0151] In some embodiments, determination of the path group type associated with the one or more path groups (e.g., the NF condition of a reflector/object associated with the path

group, with respect to the sensing receiver node), is done at the sensing receiver node based on criteria and/or conditions being satisfied. For example, the condition/criterion being satisfied may be known *a priori* and/or pre-configured. As another example, the condition/criterion being satisfied may be indicated and/or configured to the sensing receiver node by the SensMF.

[0152] Examples of the criteria/conditions used to determine the path group type include, but are not limited to, the difference (e.g., maximum-to-minimum) of (one or more or a combination of) the angle (e.g. AoA/ZoA), the delay, and/or the doppler shift of the paths (or rays or MPCs) associated with a path group/reflector object exceeding a threshold, a variance of (one or more or a combination of) the angle (e.g. AoA/ZoA), the delay, and/or the doppler shift of the paths (or rays or MPCs) associated with a path group/reflector object exceeding a threshold, a spread of (one or more or a combination of) the angle (e.g. AoA/ZoA), the delay, and/or the doppler shift of the paths (or rays or MPCs) associated with a path group/reflector object exceeding a threshold, a standard deviation of (one or more or a combination of) the angle (e.g. AoA/ZoA), the delay, and/or the doppler shift of the paths (or rays or MPCs) associated with a path group/reflector object exceeding a threshold, etc. Note that in certain embodiments the threshold amount may be indicated by the SensMF.

[0153] In some embodiments, the NF condition associated with a detected path group is determined, by the sensing receiver node, at least in part based on one or more of: A) the phase angle of the incidence wave increases/changes linearly when moving from the “k-th” element to “k+1-th” element in the array; B) the phase shift of the received signal/wave is a linear function of the distance between the elements; and/or C) the received signal amplitude at all the array elements is same (or almost the same). Note that these properties may be used as a distinguishing feature where the conditions hold for the FF condition and not for the NF condition, hence used as a distinguishing feature.

[0154] Regarding the determination/measurement and/or indication/reporting (by the sensing receiver node) of a first path group associated with a second path group, the SensMF and/or the sensing receiver node may determine, e.g., that a first path group subset/subgroup of the second group, based on the first group being associated with the same reflection

target/object/area as of the second group, and further based on the first group being the same or modified path group of a previously detected/reported path group.

[0155] For example, a path group describing a leg of a human may be associated with, as a subgroup, the path group describing the human target. As another example, the path group reflected by a leg of a human may be associated with the same target as another path group reflected by the chest of the human.

[0156] Regarding the determination/measurement and/or indication/reporting (by the sensing receiver node) of one or more of signaling path parameters and/or path group information, the sensing receiver node may measure and report signaling path parameters including, but not limited to, the AoA, the ZoA, the doppler shift, the ToA, the ToF, the carrier phase and/or channel phase, the rank of the channel associated with the path group, the number of reflections (e.g., single reflection, LOS, first arrival path), and the like.

[0157] In some embodiments, the sensing receiver node reports the signaling path parameters and/or path group information associated with all the paths of the path group. In other embodiments, the sensing receiver node reports the signaling path parameters and/or path group information associated with a representative path of the path group (i.e., a main path or head path), or for the representative paths for the path clusters/subgroups within a path group. In one embodiment, the main/representative path may be determined as a path of highest RSRPP (e.g., measured from any RS/sensing signal) within the path group (or within the path cluster/subgroup). In another embodiment, the main/representative path may be determined as the path at the center (in terms of the one or more of the path parameters, e.g., delay, AoA, ZoA) of the associated path group/cluster.

[0158] Regarding the determination/measurement and/or indication/reporting (by the sensing receiver node) of one or more statistics associated with the signaling path parameters, in various embodiments the sensing receiver node may be configured to measure and report statistics of the paths (or rays or MPCs) of a path group associated with the path parameters, such as AoA, ZoA, doppler shift, delay, ToA, ToF, channel rank, number of reflections, or combination thereof.

[0159] For example, in certain embodiments, the sensing receiver node may measure and report the average, median, expectation, spread/deviation/RMS of the AoA, ZoA, doppler shift, ToA/ToF values of the paths (or rays or MPCs) associated with a path group. In one embodiment, the sensing receiver node may report a combined/weighted average of multiple of the statistics, e.g., a weighted sum of deviation/spread of AoA, ZoA and doppler shift.

[0160] In some examples, the statistics are averaged (and/or weighted) based on the energy of each path (or ray or MPC) observed/measured at the sensing receiver node. For example, the average AoA is measured with the RSRPP or square root of RSRPP of each path (or ray or MPC). In other example the statistics are averaged (and/or weighted) based on the energy of each path group/subgroup observed/measured at the sensing receiver node.

[0161] In some embodiments, the above statistics may be generated and/or reported separately for each subgroup of the path group. In other embodiments, the above statistics may be jointly generated/reported for all or multiple of the subgroups of the path group. For example, the sensing receiver node may report the spread of AoA/delay for all paths (or rays or MPCs) of a path group. Alternatively, the sensing receiver node may report separate joint spreads for each of the path groups.

[0162] Regarding the determination/measurement and/or indication/reporting (by the sensing receiver node) of differential measurement of the paths of a path group with a reference path, in various embodiments the measurements (e.g., AoA/ZoA, ToA) of the paths (or rays or MPCs) of a path group are measured with reference to (as a difference of two values) of the corresponding value/measurement of a reference path. In certain embodiments, the sensing receiver node may report differential measurements for the AoA, the ZoA, the ToA, the channel/carrier phase (i.e., corresponding to the channel response of a path), and/or for the doppler shift.

[0163] For example, the statistical measurement (e.g., mean, deviation, etc.) of the AoA of paths of a path group may be measured utilizing the difference of the AoA value of each path (or ray or MPC) with reference to an indicated path, such as a detected LOS/first arrival path (i.e., from a signal with a determined LOS condition). In some embodiment, the reference path for differential measurement of a path group is the same for all groups (or

subgroups) associated with a path group (e.g., a LOS path observed by the sensing receiver from a transmission point is taken as the reference path of all subgroups). In some other embodiments, the reference path for measurement of different path groups (or subgroups) may be different (e.g., a selected path of each path group (or subgroup), e.g., the strongest path, the path at the center of the AoA/ZoA of the path group, the first arrival path of a path group (or subgroup)).

[0164] In some embodiments, the SensMF may indicate to a processing type the sensing receiver node is to use to identify the path group. For example, the sensing receiver node may determine the path group based on an indicated computation strategy or an artificial intelligence and/or machine learning (AI/ML) model. In such embodiments, the SensMF may indicate (e.g., in the sensing configuration) a model ID, a model type ID, a model input data type/combination, model output data type/combination, etc. Alternatively, the sensing receiver node may report to the SensMF/network the processing type used to identify the path group. For example, the sensing receiver node may indicate (e.g., in the measurement report) a model ID, a model type ID, a model input data type/combination, model output data type/combination, etc.

[0165] Regarding the determination/measurement and/or indication/reporting (by the sensing receiver node) of the number of path subgroups within a path group, in various embodiments the number of path subgroups is based on a previously indicated signaling path property, such as a maximum spread or max-to-min-distance of AoA (or delay, or doppler shift) corresponding to each path subgroup.

[0166] In some embodiments, when a path group further comprising one or multiple subgroups, a measurement quantity (e.g., any of the exemplified measurements of the above) may be defined/associated with: the paths (or rays or MPCs) belonging to the path group (e.g., the mean AoA of the rays belonging to a first path group 914 of the Case C of Figure 9); or one/each of the subgroups (e.g., the mean AoA of the paths (or rays or MPCs) belonging to each of the subgroups of the Case C of Figure 9); or multiple of the subgroups (e.g., mean AoA of the paths (or rays or MPCs) belonging to a collection of the one or more subgroups of the Case C of Figure 9); or any combination thereof.

[0167] In some embodiments, the sensing receiver node utilizes assistance information to accomplish the detection of the one or more path groups/subgroups and/or measurement of the path group/subgroups. In such embodiments, the assistance information may include one or more of: additional RAT-independent sensing data, context information, sensing signal transmission information, *a priori* information, object type information, or any combination thereof.

[0168] The additional RAT-independent sensing data may be obtained from the network or SensMF to the sensing receiver node. Alternatively, the additional RAT-independent sensing data may be obtained by an application connected to the sensing receiver node , such as an application residing on or connected to a UE device performing as a sensing receiver node. Examples of RAT-independent sensing data include, but are not limited to, camera data, radar and/or LIDAR measurements, IEEE wireless local area network (WLAN) sensing measurements, etc.

[0169] The context information may include a description of potential reflectors/sensing target objects, such as a vehicle, a pedestrian, reflector object type, and/or physical characteristics of a reflector object (e.g., size, shape, mobility pattern), an object ID, object type ID, etc. The sensing signal transmission information may include beam/transmission radiation, transmission power, transmission point position, transmission point velocity, beam direction, beam width, etc.

[0170] The *a priori* information may include a statistical distribution or statistical measure of the one or multiple parameters of the path group. For example, the *a priori* information may include an approximate or expected AoA/ZoA of the path group etc. The object type information may include an indication of the object type, or a set of possible object types, object IDs, etc.

[0171] In some embodiments, all or a subset of the parameters/information utilized at the sensing receiver node for detection and/or measurement of the path groups/subgroups (e.g., as part of the configuration parameters for sensing measurement and/or reporting, as part of the assistance information for sensing measurements, etc.), is assumed to be known (by the SensMF)/pre-configured for the sensing receiver node.

[0172] In some embodiments, all or a subset of the parameters/information utilized at the sensing receiver node for detection and/or measurement of the path groups/subgroups, is indicated to the sensing receiver node as part of the sensing configuration parameters (i.e., for the sensing measurement and reporting). In other words, the sensing configuration may be the source of at least a portion of the parameters/information utilized at the sensing receiver node for detection and/or measurement of the path groups/subgroups.

[0173] In some embodiments, all or a subset of the parameters/information utilized at the sensing receiver node for detection and/or measurement of the path groups/subgroups is obtained and/or determined autonomously by the sensing receiver node. For example, the sensing receiver node may make this determination via an application or higher layer information, associated with a sensing task known to the sensing receiver node (e.g., via an application residing on or connected to the sensing receiver node).

[0174] In some embodiments, the detection and/or measurement of the one or more path groups/subgroups are performed at a radio node via utilization of a computational model (e.g., AI model and/or ML model). As described above, the SensMF may indicate a computation model that the sensing receiver node is to use to detect and/or measure the one or more path groups/subgroups. In another embodiment, the sensing receiver node may indicate to the SensMF the computation model used to detect and/or measure the one or more path groups/subgroups.

[0175] In some embodiments, when the processing/measurement associated with the sensing measurement (i.e., for detection and/or measurements of parameters of a path group) are done based on a computational model (e.g., an AI/ML model), the input information for the model may include at least one or more of: parameters of the detected/measured paths (or rays or MPCs); parameters of the transmitted one or more sensing signals; parameters of the received one or more sensing signals; or any combination thereof.

[0176] The parameters of the detected/measured paths (or rays or MPCs) may include one or more of AoA, ZoA, ToA, ToF, doppler shift, channel/carrier phase (corresponding to the channel response of a path) which can be measured/obtained at different time instances,

based on different sensing signals of one or different transmission points, or a combination thereof.

[0177] The parameters of the transmitted one or more sensing signals may include signal type, e.g., PRS, time-frequency resources, transmission periods/periodicity, the sequence or sequence generation parameters (e.g., parameters describing a Zadoff-Chu sequence), transmission radiation pattern/transmitter beam information (e.g., transmitter beam AoD and/or ZoD, beamwidth at the azimuth/elevation directions).

[0178] The parameters of the received one or more sensing signals, corresponding to the one or more transmitted sensing signals, may include the information of the sensing signal reception, such as time/timestamp of reception, reception beam ID, reception beam angle, reception beam width, etc.

[0179] In further embodiments, the input information for the model may additionally include all or subset of the parameters of sensing measurement/reporting configuration and/or related assistance information described above.

[0180] In some embodiments, when the processing/measurement associated with the sensing measurement (i.e., for detection and/or measurements of parameters of a path group) are done based on a computational model (e.g., an AI/ML model), the output information for the model may include at least one or more of: a measurement quantity, a feature of the reflective object, or any one or combination of the sensing measurement/reporting quantities as described above.

[0181] In certain embodiments, the measurement quantity is defined with the utilization of the AI/ML model on an indicated/defined input. For example, the report may include a measurement quantity of one or more of the model type *X* and/or model ID *Y*, obtained from the sensing signal/RS ID *Z*. In another example, the measurement quantity of one or more of the model type *X* and the output *Q* of the model type *X* and/or model ID *Y*, obtained from the sensing signal/RS ID *Z*.

[0182] In certain embodiments, the feature of a reflective object for which the path group/subgroups are detected and/or measured may include (or indicate) the shape of an

object, orientation of the object, heading of an object, dimension of an object, or a combination thereof.

[0183] In certain embodiments, the feature of a reflective object for which the path group/subgroups are detected and/or measured may include (or indicate) an object type, for example, the selection of an object type among predefined or previously measured/identified set of object types.

[0184] In certain embodiments, the feature of a reflective object for which the path group/subgroups are detected and/or measured may include (or indicate) the object ID, for example, selected from among a pre-defined or previously known/measured/detected set of objects.

[0185] In certain embodiments, the feature of a reflective object for which the path group/subgroups are detected and/or measured may include (or indicate) object movement type, for example, the selection of type of an object movement among predefined or previously identified/measured set of movements. In some implementations, the movement type may be a hand/body gesture, rotation movement, etc., and a velocity/magnitude/speed associated with the object movement.

[0186] In some embodiments, when processing/measurement associated with the sensing measurement done based on a computational model (e.g., an AI/ML model), the computational model may be previously transferred to the sensing receiver node (e.g., from the network or SensMF) and/or the model has been available at the sensing receiver node and wherein the availability may be indicated to the network/SensMF (e.g., as part of the sensing receiver node capability information for sensing measurements).

[0187] In some embodiments, the SensMF and/or network may configure the sensing receiver node with a training period for a computational model (e.g., AI/ML model), wherein configuration of the training period may comprise an indication of the time-frequency of the sensing signals and the type of the data/label (e.g., true/correct property of the reflector, true/correct path group parameter, etc.) transferred during the training period, the type of the model to be trained (a type ID, wherein model of a specific type follows one or more of the input data type/format/structure, output data type/format/structure, model (number and size

of each input, output and intermediate layers) dimension, activation function, training type, etc. to generate the output data from the input data), the model to be trained (model ID), or a combination thereof.

[0188] In some embodiments, the information transferred to the sensing receiver node during the training period by the SensMF may comprise at least all or subset of the measurement/reporting configuration elements as described above, the true/correct value of the one or more of the model output as described above, or one or more assistance information comprising the sensing data of non-3GPP/RAT-independent sensing data (e.g., camera data). In some embodiments, the training request may be initiated by the sensing receiver node, e.g., determined autonomously or based on observation/testing of some indicated criteria by the SensMF (measurement error/unreliability exceeds a threshold) or determined by the SensMF (e.g., based on the reception of the model outcome/report and observing accuracy of the report).

[0189] In some embodiments, the sensing receiver node is further equipped with and/or connected to a non-3GPP or RAT independent sensing data (e.g., camera, a motion sensor, RGB sensor, other sensor). As such, the radio node may directly utilize the non-3GPP data, when available, for the purpose of training of the model. In one such example, when the sensing receiver node obtains a RAT-independent data (e.g., camera/RGB sensor data reading) of a particular angle/condition including observation/detection of an object at the camera view point, and upon determination for a need for training of the AI/ML model, the sensing receiver node requests a training period with the indication of the availability of the non-3GPP data at the view point. In some examples, the sensing receiver node further transmits to the SensMF the information of the observed object, e.g., information of the detected object, the measurement parameters of the visual rays received at the sensing receiver node from the object, or the raw/compressed non-3GPP data at the viewpoint.

[0190] Upon reception of the training request, the SensMF and/or network may configure the training period. In some embodiments, when the sensing receiver node determines the AI/ML model has reached a sufficient accuracy (e.g., utilizing its available non-3GPP data to determine the true state of environment or utilizing the information from the SensMF on the true reflector object/path/path group parameters) it indicates the termination of the training

request, based on which the SensMF may terminate configuration and/or transmission of the sensing signal and the training period.

[0191] In some embodiments, the sensing receiver node measures and reports on a detected path group (by the sensing receiver node) or on a known path group by the sensing receiver node (e.g., indicated by a path group ID from a previously measured or known path group, or indicated by a reflector/object ID detected/known from a previous measurement by the sensing receiver node) comprising a combination of transmission direction (e.g., a SL direction, DL direction, UL direction, and/or TRP2TRP direction), a sensing signal ID/parameters such as an RS ID (e.g., a PRS, SRS, CSI-RS, sensing dedicated RS, etc.) and a measurement type (e.g., average, or standard deviation, or root mean square (RMS), or mean value of the AoA, ZoA, doppler shift, ToA/ToF, carrier phase of a path group, Rx-Tx time difference of the path group, RS time difference (RSTD), RS doppler difference (RSDD), AoA difference, ZoA difference of the path group with a reference path), or combination thereof.

[0192] In one example, the sensing receiver node measures and reports the DL PRS RSTD as the difference between the average/mean ToA of the detected path group and a reference path, e.g., indicated to and/or known by the SensMF and the sensing receiver (such as the first arrival path of the same DL PRS).

[0193] In another example, the sensing receiver node measures and reports the TRP2TRP CSI-RS RSDD as the difference between the average/mean doppler shift of the detected path group and a reference path, e.g., indicated to and/or known by the SensMF and the sensing receiver (such as the first arrival path of the same DL PRS).

[0194] In one example, the sensing receiver node measures and reports the UL SRS AoA/ZoA spread (or doppler shift spread, or carrier phase spread, or ToA/ToF spread) as the spread, or RMS, or variance, or difference between the maximum and minimum of the AoA/ZoA (or doppler shift, or carrier phase, or ToAs/ToFs) of the path group.

[0195] In one example, the sensing receiver node measures and reports the UL SRS mean/average AoA/ZoA (or doppler shift, or carrier phase, or ToA/ToF) as the mean/expected AoA/ZoA (or doppler shift, or carrier phase, or ToA/ToF) of the path group.

[0196] In one implementation, the sensing receiver node detects the path group (e.g., as being a path group and not a single path/ray) based on the delay of the paths of the path group (e.g., the difference/spread of the path delay among the group as observed by the sensing receiver node). Thereafter, the sensing receiver node detects the NF condition towards a target based on the measurement of the AoA/ZoA difference/spread among the paths of the path group. In some embodiments, the indication by the sensing receiver node to the SensMF of detection/presence of a path group is done separately from the indication of the NF condition towards the associated reflector, e.g., first the path group detection is indicated, and then (e.g., perhaps upon request of the SensMF) the sensing receiver node reports a detected NF condition.

[0197] In some embodiments, any of the configurations, or indications, or reports of the quantities described herein (e.g., the measurement quantities, reporting quantities, configuration parameters, assistance information, etc.) are indicated via an index from a codebook of the possible values of the quantity or reporting parameter.

[0198] In one embodiment, when the NF condition is indicated by the sensing receiver node on a path group and/or when a path group is detected by a sensing receiver node of being associated with a reflector object of an NF condition, then the reporting of the path group with/without NF condition is assumed to be done with a codebook corresponding to a path group associated with (or not associated with, respectively) an NF condition, wherein the two codebooks are different in that the codebook associated with the NF condition of a path group comprises, at least, information representative of the observed path AoA/ZoA of the group of paths (including AoA/ZoA of multiple paths, AoA/ZoA average of paths of the path group, AoA/ZoA spread of paths of the path group or a combination thereof).

[0199] In some embodiments, the NF condition and/or a type of a path group, corresponds to the condition that a detected path group may not be reported with a single AoA/ZoA value corresponding to the path condition of all paths, and hence multiple AoA/ZoA values, an AoA/ZoA average/mean or spread/variance of the AoA/ZoA needs to be reported to the SensMF. In some examples, the indication of a path group means that for at least one or more of the quantities of ToA, ToF (or receiver-to-transmitter time difference) and doppler shift of the path, a path group shall be associated with at least two values of the

quantity and/or a mean (or average, or variance, or spread, or standard deviation, or RMS) of at least one of the quantities.

[0200] In some embodiments, a type of path group/subgroup is indicated (via one or more index from a codebook). For example, the type of path group may be indicated in addition to the detection/reporting of the presence of a path group/subgroup. In some embodiments, the path group/subgroup type may inform that the paths of the path group/subgroup are not identical in the path delay, path doppler, path AoA, path ZoA, carrier phase. In certain embodiments, the path group/subgroup type may indicate the channel rank corresponding to the path group. In certain embodiments, the path group/subgroup type may indicate the number of reflections/bounces that the paths of the path group have experienced. In certain embodiments, the path group/subgroup type may indicate the number of the differentiable path subgroups within a path group, or combination thereof.

[0201] Table 1 depicts some example types of the path group. Note that the measurement quantities associated with the path group type can be assumed by the sensing receiver node as related measurements to the corresponding path group type.

Table 1: Path group types that may be detected/identified and reported by a sensing receiver node.

Type Index	Description	Measurement Quantities Associated with the Path Group Type
A	The paths of the path group/subgroup are not identical in the path delay/ToA with at least a known/indicated threshold (e.g., one or multiple sample time of the sensing receiver node processing).	AoA/ZoA/ToA/delay average/median, spread/variance, maximum-min distance
B	The paths of the path group/subgroup are not identical in the path AoA with at least a known/indicated threshold (e.g., one or multiple AoA measurement resolution of the sensing receiver node)	AoA/ZoA/ToA/delay average/median, spread/variance, maximum-min distance
C	The paths of the path group/subgroup are not identical in the path AoA and ZoA with at least a known/indicated threshold	AoA/ZoA average/median, spread/variance, maximum-min distance, a joint AoA and ZoA distance/spread

D	The paths of the path group/subgroup are not identical in the path doppler shift with at least a known/indicated threshold.	Doppler shift average/median, spread/variance, maximum-min distance
E	The channel corresponding to the path group is of rank [2 - 4]	Corresponding channel rank
..	..	..

[0202] In some embodiments, upon indication of the type of the path group, the type of the measurement quantity (and the codebook for reporting of the measurement quantity) by the sensing receiver node shall be assumed implicitly based on the one or more of: A) the requested/configured measurement received from the SensMF, B) the detected and indicated type of the path group, and/or C) the reporting configuration received from the SensMF. In one implementation, the SensMF configures the sensing receiver node with a DL PRS and further with measurement of a path AoA and a path doppler shift. Upon detection of a path group of the type *"The paths of the path group/subgroup are not identical in the path AoA with at least a known/indicated threshold*" based on a received threshold from the SensMF, the sensing receiver node indicates the presence of the path group with indication of the type and further measures and reports the path AoA as a mean and spread (or deviation or RMS) if the AoA values of the path group utilizing the measurement codebook defined for reporting of the AoA mean/average and the AoA spread/deviation.

[0203] In some other embodiments, the detected path group type is indicated implicitly (by the sensing receiver node) or inferred (by the SensMF node) from the reported measurement quantity/type of the sensing receiver node. In one implementation, the SensMF configures the sensing receiver node with a DL PRS and with a measurement of a path AoA and a path doppler shift of path/rays associated with a sensing target object, e.g., target described/defined based on the expected characteristics of the paths in terms of the doppler shift, AoA/ZoA, ToA range. Upon detection of a path group of the type *"The paths of the path group/subgroup are not identical in the path AoA with at least a known/indicated threshold*," the sensing receiver node then reports a path AoA/doppler shift as a mean/average of the AoA/doppler shift of the detected path group, and further reports a path AoA spread/variance/distance to the SensMF, including that the reported AoA spread is associated with the path group for which the AoA quantity has been reported.

[0204] Furthermore, the sensing receiver node does not report any doppler shift spread (or variance, or distance) associated with the path group associated with the previously reported AoA spread, at least within a predetermined time window assumed by the SensMF (and potentially indicated to the sensing receiver node). As such, the SensMF shall assume the path group type of the *"The paths of the path group/subgroup are not identical in the path AoA with at least a known/indicated threshold*," based on the received measurement reports from the sensing receiver node.

[0205] In some embodiments, the SensMF further indicates a timer value or time window is to the sensing receiver node, wherein subsequent to detection of a path group the sensing receiver node shall indicate the type of the path group (e.g., implicitly, explicitly, or upon determination of the sensing receiver node), based on the explicit indications and/or the reported measurement quantities (implicitly).

[0206] In some embodiments, the codebook for reporting of an average/mean and/or reporting of a spread value is similar (and in some other embodiments, not similar) to the codebook for reporting of the quantity of a single path. For example, the average AoA/ZoA, (or power, or delay, or ToA/ToF, or doppler shift) of paths of a path group may be reported using the same codebook as for the reporting of the AoA/ZoA (or power, or delay, or ToA/ToF, or doppler shift) of a single path.

[0207] In some embodiments, the reporting of a path group is triggered once a configured/indicated feature of a path group is detected, e.g., when as an outcome of a computational AI/ML model a gesture/pose of a reflector object is detected. Upon detection of a path group or detection of the feature of the path group, in some embodiments, the sensing receiver node determines a closest occasion among the configured reporting occasions and reports the detected feature/gesture (e.g., by transmitting an index indicating the detected feature).

[0208] In some embodiments, the feature of the path group (to be detected by the radio node and/or reported to the SensMF) may include one or more of: A) a shape; B) an observed energy distribution or pattern; C) a group blockage; D) a blockage duration; or any combination thereof.

[0209] Regarding the shape feature of the path group, in one embodiment this feature may be indicated as a rectangular shape (e.g., with dimension X,Y), or as a circular shape (e.g., with radius R and center C). In another embodiment, the shape may be indicated by plurality of vertices defining the shape (e.g., as a convex hull).

[0210] Regarding the observed energy distribution/pattern for the path group, in one implementation this feature is indicated as a ratio of the energy contained in the center or dominant path of the path group. In another implementation, this feature is indicated as an energy ratio between two parts of the path group. In yet another implementation, this feature is indicated as energy spread, power spread, energy variation or power variation of the paths (e.g., of different delay) within the path group.

[0211] Regarding the group blockage, this feature may be indicated as a blockage of the all or a subset of the paths of the path group. Regarding the blockage duration, this feature may be indicated as the duration of the group blockage of the path group.

[0212] In some embodiments, the SensMF indicates to a radio node (e.g., sensing receiver node) that a configured/expected path group (e.g., indicated by the SensMF), or a path detected (e.g., measured) by the radio node, is associated with a previously defined path group (e.g., previously detected and/or measured path group), thereby indicating that they are the same paths, or associated with the same reflector/object, etc.

[0213] In some embodiments, the detection and/or measurement of the path group is done at a network radio node (e.g., gNB). Here, the detection and/or measurement may be based on an UL sensing signal transmission, or a DL sensing signal transmission of another network node, or a sensing signal transmission in the TRP2TRP direction (e.g., signal transmitted by a TRP not intended primarily for the DL reception of a UE, but for reception by the network radio node (e.g., gNB) for performing measurements). In certain embodiments, the sensing signal transmission in the TRP2TRP direction may be synchronized on the DL frame, UL frame, of the first (i.e., transmitting) TRP and/or the second (receiving) TRP. In some embodiments the time/frequency synchronization reference of the sensing signal is indicated to the radio node as part of the configuration/definition of the sensing signal.

[0214] In some embodiments, a reflector entity associated with a path group may be a known object (e.g., known by the sensing receiver and/or the SensMF), an unknown reflector object as part of the environment, a sensing target object, or a network entity (a RIS, an NCR, etc.). In some embodiments, when the path group is associated with a network entity, the presence and/or reflector property of the path group is indicated by the SensMF to the sensing receiver node. For example, the reflector property may include the reflector size (dimensions), mobility pattern, expected ToA/AoA/ZoA spread at the target node location, or any combination thereof.

[0215] In one embodiment, when the path group associated with a known reflector is detected and reported by the sensing receiver node, and wherein the report comprises an AoA/ZoA spread or a relation between the AoA/ZoA spread (e.g., the AoA spread is two-fold of the ZoA spread according to the measurement/receiver node's observation/measurement), then the reported spread of the AoA/ZoA may be further reported to a controller entity for estimating the position of the measurement/receiver node. Note that this embodiment is not directed at a sensing operation, but rather a positioning operation, where the sensing receiver node is the target for which the node position is to be estimated. Accordingly, the sensing receiver node performs measurements based on the received signals, which can be any of the sensing signals described herein. As such, the position of the measurement/receiver node is estimated at a controller node (e.g., LMF) at least in part, based on the observed AoA spread/max-min-distance, ZoA/spread/max-min-distance and/or their relation/ratio as reported by the receiver node.

[0216] Note that in the above embodiments, including the positioning of a target UE, the terms "sensing signal" refers to the signals by which measurements for positioning (e.g., of a target UE) is done. Moreover, the terms "sensing transmitter" and "sensing receiver" refer to the radio nodes transmitting and receiving the sensing signals.

[0217] **Figure 10** illustrates an example of a UE 1000 in accordance with aspects of the present disclosure. The UE 1000 may include a processor 1002, a memory 1004, a controller 1006, and a transceiver 1008. The processor 1002, the memory 1004, the controller 1006, or the transceiver 1008, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described

herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0218] The processor 1002, the memory 1004, the controller 1006, or the transceiver 1008, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0219] The processor 1002 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a central processing unit (CPU), an ASIC, a field programmable gate array (FPGA), or any combination thereof). In some implementations, the processor 1002 may be configured to operate the memory 1004. In some other implementations, the memory 1004 may be integrated into the processor 1002. The processor 1002 may be configured to execute computer-readable instructions stored in the memory 1004 to cause the UE 1000 to perform various functions of the present disclosure.

[0220] The memory 1004 may include volatile or non-volatile memory. The memory 1004 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1002, cause the UE 1000 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 1004 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0221] In some implementations, the processor 1002 and the memory 1004 coupled with the processor 1002 may be configured to cause the UE 1000 to perform various functions (e.g., operations, signaling) of a radio node (e.g., sensing transmitter node and/or sensing receiver node) described herein (e.g., executing, by the processor 1002, instructions stored in the memory 1004). In some implementations, the processor 1002 may include multiple

processors and the memory 1004 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may be individually or collectively, configured to perform various functions (e.g., operations, signaling) of the UE 1000 as disclosed herein.

[0222] The processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to receive one or more sensing signals and performing a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration. In one implementation, the sensing configuration is received from the network (e.g., from a SensMF or configuring node). In another implementation, the sensing configuration is pre-configured or known *a priori* at the UE 1000. In yet another implementation, the sensing configuration is self-determined (i.e., determined autonomously by the UE 1000). In some implementations, the sensing procedure is further based on an NF condition of one or more sensing signals observable at the UE 1000.

[0223] The processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to determine a path group based at least in part on the sensing procedure, where the path group comprises a plurality of paths (or rays, or MPCs) associated with one or more shared signaling path properties. In some implementations, the sensing configuration comprises at least one criteria for detection of the path group based on the one or more shared signaling path properties.

[0224] The processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to transmit a report comprising a set of one or more measurement quantities associated with the path group. In some implementations, the report further comprises an indication of the NF condition of a reflector object associated with the path group.

[0225] In some implementations, the report further comprises an indication of a path group type based on the one or more shared signaling path properties. In certain implementations, the indication of the path group type comprises an index from a codebook (or table) of expected path group types.

[0226] In certain implementations, at least one property of the one or more shared signaling path properties differ among the paths of the path group and satisfies a variation threshold. In one implementation, the variation threshold is a maximum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is less than the maximum variation. In another implementation, the variation threshold is a minimum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is greater than the minimum variation. In further implementations, the variation threshold may include both a maximum variation and a minimum variation.

[0227] In certain implementations, the one or more shared signaling path properties comprise one or more of: A) a path ToA for the path group; B) a path ToF for the path group; C) a path delay for the path group; D) a path AoA for the path group; E) a path ZoA for the path group; F) a path doppler shift for the path group; G) a path channel phase for the path group; or H) a RSRPP; or a combination thereof.

[0228] In certain implementations, the set of one or more measurement quantities associated with the path group is based on the path group type. In further implementations, the indication of a path group type comprises an implicit indication signaled by an inclusion in the report of one or more measurement quantities associated with the path group type.

[0229] In some implementations, the processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to: A) receive an indication of a time window associated with the sensing procedure; B) determine the path group type based on the sensing procedure; and C) transmit an indication of the path group type during the time window.

[0230] In some implementations, the set of one or more measurement quantities associated with the path group comprises one or more of: A) an average ToA of the paths of the path group; B) a spread or variance of the ToA of the paths of the path group; C) an average ToF of the paths of the path group; D) a spread or variance of the ToF of the paths of the path group; E) an average delay of the paths of the path group; F) a spread or variance of the delay of the paths of the path group; G) an average AoA of the paths of the path group;

H) a spread or variance of the AoA of the paths of the path group; I) an average ZoA of the paths of the path group; J) a spread or variance of the ZoA of the paths of the path group; K) an average doppler shift of the paths of the path group; L) a spread or variance of the doppler shift of the paths of the path group; M) an average channel phase of the paths of the path group; or N) a spread or variance of the channel phase of the paths of the path group; or a combination thereof.

[0231] In some implementations, the processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to receive assistance information including an indication of a reflector entity associated with the path group. In one implementation, the assistance information may be included in the sensing configuration. In certain implementations, the assistance information may include one or more properties of the reflector, including one or more of: A) a size of the reflector; B) a mobility pattern of the reflector; C) an expected ToA spread associated with the reflector; D) an expected AoA spread associated with the reflector; or E) an expected ZoA spread associated with the reflector; or a combination thereof.

[0232] In certain implementations, the report further comprises one or more of: A) an observed ToA spread associated with the reflector; B) an observed AoA spread associated with the reflector; or C) an observed ZoA spread associated with the reflector; or a combination thereof. Such information may be used by the network and/or SensMF to determine positioning information of the UE 1000.

[0233] In some implementations, the sensing configuration for the sensing procedure is received from a configuring entity, such as a SF or a SensMF. In certain implementations, the sensing configuration may be received from a RAN node associated with the UE 1000. In other implementations, the sensing configuration for the sensing procedure may instead be determined by the UE 1000.

[0234] In various implementations, the UE 1000 may support various functions (e.g., operations, signaling) of a SensMF, in accordance with examples as disclosed herein (e.g., executing, by the processor 1002, instructions stored in the memory 1004). For example, the processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable

to cause the UE 1000 to transmit a sensing configuration for a sensing procedure, based on one or more sensing signals. In some implementations, the sensing configuration comprises at least one criteria for detection of a path group based on the one or more shared signaling path properties.

[0235] The processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to receive a report comprising a set of one or more measurement quantities associated with a plurality of paths. The processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to associate the plurality of paths with a path group, where the path group comprises a set of paths (or rays, or MPCs) associated with one or more shared signaling path properties.

[0236] In some implementations, the processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to: A) receive a subsequent measurement quantity within a predetermined time window; and B) associate the plurality of paths with the path group based at least in part on the subsequent measurement quantity.

[0237] In some implementations, the processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to transmit assistance information comprising an indication of a reflector entity associated with the path group. In such implementations, the report further comprises one or more of: A) an observed ToA spread associated with the reflector; B) an observed AoA spread associated with the reflector; or C) an observed ZoA spread associated with the reflector; or a combination thereof. In further implementations, the processor 1002 coupled with the memory 1004 may be configured to, capable of, or operable to cause the UE 1000 to determine positioning information associated with a sensing measurement node based at least in part on a location of the reflector entity and one or more of: the observed ToA spread, the observed AoA spread, or the observed ZoA spread, or a combination thereof.

[0238] In some implementations, the assistance information further comprises one or more properties of the reflector, including one or more of: A) a size of the reflector; B) a mobility pattern of the reflector; C) an expected ToA spread associated with the reflector; D) an expected AoA spread associated with the reflector; or E) an expected ZoA spread

associated with the reflector; or a combination thereof. In one implementation, the assistance information may be included in the sensing configuration.

[0239] In some implementations, the one or more shared signaling path properties comprise one or more of: A) a path ToA for the path group; B) a path ToF for the path group; C) a path delay for the path group; D) a path AoA for the path group; E) a path ZoA for the path group; F) a path doppler shift for the path group; G) a path channel phase for the path group; or H) a RSRPP; or a combination thereof.

[0240] In certain implementations, the indication of the path group type comprises an index from a codebook (or table) of expected path group types. In certain implementations, the set of one or more measurement quantities associated with the path group is based on the path group type. In further implementations, the indication of a path group type may be an implicit indication signaled by an inclusion in the report of one or more measurement quantities associated with the path group type.

[0241] In some implementations, the report further comprises an indication of the NF condition of a reflector object associated with the path group. In some implementations, the report further comprises an indication of a path group type based on the one or more shared signaling path properties. In such implementations, the one or more shared signaling path properties differ among the paths of the path group and satisfies a variation threshold. In one implementation, the variation threshold is a maximum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is less than the maximum variation. In another implementation, the variation threshold is a minimum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is greater than the minimum variation. In further implementations, the variation threshold may include both a maximum variation and a minimum variation.

[0242] In some implementations, the set of one or more measurement quantities associated with the path group comprises one or more of: A) an average ToA of the paths of the path group; B) a spread or variance of the ToA of the paths of the path group; C) an average ToF of the paths of the path group; D) a spread or variance of the ToF of the paths of the path group; E) an average delay of the paths of the path group; F) a spread or variance of

the delay of the paths of the path group; G) an average AoA of the paths of the path group; H) a spread or variance of the AoA of the paths of the path group; I) an average ZoA of the paths of the path group; J) a spread or variance of the ZoA of the paths of the path group; K) an average doppler shift of the paths of the path group; L) a spread or variance of the doppler shift of the paths of the path group; M) an average channel phase of the paths of the path group; or N) a spread or variance of the channel phase of the paths of the path group; or a combination thereof.

[0243] The controller 1006 may manage input and output signals for the UE 1000. The controller 1006 may also manage peripherals not integrated into the UE 1000. In some implementations, the controller 1006 may utilize an operating system (OS) such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 1006 may be implemented as part of the processor 1002.

[0244] In some implementations, the UE 1000 may include at least one transceiver 1008. In some other implementations, the UE 1000 may have more than one transceiver 1008. The transceiver 1008 may represent a wireless transceiver. The transceiver 1008 may include one or more receiver chains 1010, one or more transmitter chains 1012, or a combination thereof.

[0245] A receiver chain 1010 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1010 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 1010 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 1010 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1010 may include at least one decoder for decoding/ processing the demodulated signal to receive the transmitted data.

[0246] A transmitter chain 1012 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1012 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or

more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 1012 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1012 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0247] **Figure 11** illustrates an example of a processor 1100 in accordance with aspects of the present disclosure. The processor 1100 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 1100 may include a controller 1102 configured to perform various operations in accordance with examples as described herein. The processor 1100 may optionally include at least one memory 1104, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 1100 may optionally include one or more arithmetic-logic units (ALUs) 1106. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0248] The processor 1100 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 1100)) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0249] The controller 1102 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 1100 to cause the processor 1100 to support various operations in accordance with examples

as described herein. For example, the controller 1102 may operate as a control unit of the processor 1100, generating control signals that manage the operation of various components of the processor 1100. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0250] The controller 1102 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 1104 and determine subsequent instruction(s) to be executed to cause the processor 1100 to support various operations in accordance with examples as described herein. The controller 1102 may be configured to track memory address of instructions associated with the memory 1104. The controller 1102 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 1102 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 1100 to cause the processor 1100 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 1102 may be configured to manage flow of data within the processor 1100. The controller 1102 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 1100.

[0251] The memory 1104 may include one or more caches (e.g., memory local to or included in the processor 1100) or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 1104 may reside within or on a processor chipset (e.g., local to the processor 1100). In some other implementations, the memory 1104 may reside external to the processor chipset (e.g., remote to the processor 1100).

[0252] The memory 1104 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1100, cause the processor 1100 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 1102 and/or the processor 1100 may be configured to execute computer-readable instructions stored in the memory 1104 to cause the processor 1100 to perform various functions. For example, the processor 1100 and/or the controller 1102 may be coupled with

or to the memory 1104, the processor 1100, the controller 1102, and the memory 1104 may be configured to perform various functions described herein. In some examples, the processor 1100 may include multiple processors and the memory 1104 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0253] The one or more ALUs 1106 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 1106 may reside within or on a processor chipset (e.g., the processor 1100). In some other implementations, the one or more ALUs 1106 may reside external to the processor chipset (e.g., the processor 1100). One or more ALUs 1106 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 1106 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 1106 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 1106 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 1106 to handle conditional operations, comparisons, and bitwise operations.

[0254] In various implementations, the processor 1100 may support various functions (e.g., operations, signaling) of a radio node (e.g., a sensing transmitter node and/or a sensing receiver node), in accordance with examples as disclosed herein. For example, the controller 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the processor 1100 to receive one or more sensing signals; perform a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration; determine a path group based at least in part on the sensing procedure, where the path group comprises a plurality of paths (or rays, or MPCs) associated with one or more shared signaling path properties; and transmit a report comprising a set of one or more measurement quantities associated with the path group.

[0255] In various implementations, the processor 1100 may support various functions (e.g., operations, signaling) of a SensMF, in accordance with examples as disclosed herein. For example, the controller 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the processor 1100 to transmit a sensing configuration for a sensing procedure, based on one or more sensing signals; receive a report comprising a set of one or more measurement quantities associated with a plurality of paths; and associate the plurality of paths with a path group, where the path group comprises a set of paths (or rays, or MPCs) associated with one or more shared signaling path properties.

[0256] Additionally, the controller 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the processor 1100 to perform one or more functions (e.g., operations, signaling) of the UE as described herein. Alternatively, the controller 1102 coupled with the memory 1104 may be configured to, capable of, or operable to cause the processor 1100 to perform one or more functions (e.g., operations, signaling) of the base station as described herein.

[0257] **Figure 12** illustrates an example of an NE 1200 in accordance with aspects of the present disclosure. The NE 1200 may include a processor 1202, a memory 1204, a controller 1206, and a transceiver 1208. The processor 1202, the memory 1204, the controller 1206, or the transceiver 1208, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0258] The processor 1202, the memory 1204, the controller 1206, or the transceiver 1208, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0259] The processor 1202 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some

implementations, the processor 1202 may be configured to operate the memory 1204. In some other implementations, the memory 1204 may be integrated into the processor 1202. The processor 1202 may be configured to execute computer-readable instructions stored in the memory 1204 to cause the NE 1200 to perform various functions of the present disclosure.

[0260] The memory 1204 may include volatile or non-volatile memory. The memory 1204 may store computer-readable, computer-executable code including instructions when executed by the processor 1202 cause the NE 1200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 1204 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0261] In various implementations, the processor 1202 and the memory 1204 coupled with the processor 1202 may be configured to cause the NE 1200 to perform various functions (e.g., operations, signaling) described herein (e.g., executing, by the processor 1202, instructions stored in the memory 1204). In some implementations, the processor 1202 may include multiple processors and the memory 1204 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may be individually or collectively, configured to perform various functions (e.g., operations, signaling) of the NE 1200 as disclosed herein.

[0262] The processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to receive one or more sensing signals and performing a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration. In one implementation, the sensing configuration is received from the network (e.g., from a SensMF or configuring node). In another implementation, the sensing configuration is pre-configured or known *a priori* at the NE 1200. In yet another implementation, the sensing configuration is self-determined (i.e., determined autonomously

by the NE 1200). In some implementations, the sensing procedure is further based on an NF condition of one or more sensing signals observable at the NE 1200.

[0263] The processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to determine a path group based at least in part on the sensing procedure, where the path group comprises a plurality of paths (or rays, or MPCs) associated with one or more shared signaling path properties. In some implementations, the sensing configuration comprises at least one criteria for detection of the path group based on the one or more shared signaling path properties.

[0264] The processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to transmit a report comprising a set of one or more measurement quantities associated with the path group. In some implementations, the report further comprises an indication of the NF condition of a reflector object associated with the path group.

[0265] In some implementations, the report further comprises an indication of a path group type based on the one or more shared signaling path properties. In certain implementations, the indication of the path group type comprises an index from a codebook (or table) of expected path group types.

[0266] In certain implementations, at least one property of the one or more shared signaling path properties differ among the paths of the path group and satisfies a variation threshold. In one implementation, the variation threshold is a maximum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is less than the maximum variation. In another implementation, the variation threshold is a minimum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is greater than the minimum variation. In further implementations, the variation threshold may include both a maximum variation and a minimum variation.

[0267] In certain implementations, the one or more shared signaling path properties comprise one or more of: A) a path ToA for the path group; B) a path ToF for the path group; C) a path delay for the path group; D) a path AoA for the path group; E) a path ZoA for the

path group; F) a path doppler shift for the path group; G) a path channel phase for the path group; or H) a RSRPP; or a combination thereof.

[0268] In certain implementations, the set of one or more measurement quantities associated with the path group is based on the path group type. In further implementations, the indication of a path group type comprises an implicit indication signaled by an inclusion in the report of one or more measurement quantities associated with the path group type.

[0269] In some implementations, the processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to: A) receive an indication of a time window associated with the sensing procedure; B) determine the path group type based on the sensing procedure; and C) transmit an indication of the path group type during the time window.

[0270] In some implementations, the set of one or more measurement quantities associated with the path group comprises one or more of: A) an average ToA of the paths of the path group; B) a spread or variance of the ToA of the paths of the path group; C) an average ToF of the paths of the path group; D) a spread or variance of the ToF of the paths of the path group; E) an average delay of the paths of the path group; F) a spread or variance of the delay of the paths of the path group; G) an average AoA of the paths of the path group; H) a spread or variance of the AoA of the paths of the path group; I) an average ZoA of the paths of the path group; J) a spread or variance of the ZoA of the paths of the path group; K) an average doppler shift of the paths of the path group; L) a spread or variance of the doppler shift of the paths of the path group; M) an average channel phase of the paths of the path group; or N) a spread or variance of the channel phase of the paths of the path group; or a combination thereof.

[0271] In some implementations, the processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to receive assistance information including an indication of a reflector entity associated with the path group. In one implementation, the assistance information may be included in the sensing configuration. In certain implementations, the assistance information may include one or more properties of the reflector, including one or more of: A) a size of the reflector; B) a mobility pattern of the

reflector; C) an expected ToA spread associated with the reflector; D) an expected AoA spread associated with the reflector; or E) an expected ZoA spread associated with the reflector; or a combination thereof.

[0272] In certain implementations, the report further comprises one or more of: A) an observed ToA spread associated with the reflector; B) an observed AoA spread associated with the reflector; or C) an observed ZoA spread associated with the reflector; or a combination thereof. Such information may be used by the network and/or SensMF to determine positioning information of the NE 1200.

[0273] In some implementations, the sensing configuration for the sensing procedure is received from a configuring entity, such as a SF or a SensMF. In certain implementations, the sensing configuration may be received from a RAN node associated with the NE 1200. In other implementations, the sensing configuration for the sensing procedure may instead be determined by the NE 1200.

[0274] In various implementations, the NE 1200 may support various functions (e.g., operations, signaling) of a SensMF, in accordance with examples as disclosed herein (e.g., executing, by the processor 1202, instructions stored in the memory 1204). For example, the processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to transmit a sensing configuration for a sensing procedure, based on one or more sensing signals. In some implementations, the sensing configuration comprises at least one criteria for detection of a path group based on the one or more shared signaling path properties.

[0275] The processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to receive a report comprising a set of one or more measurement quantities associated with a plurality of paths. The processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to associate the plurality of paths with a path group, where the path group comprises a set of paths (or rays, or MPCs) associated with one or more shared signaling path properties.

[0276] In some implementations, the processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to: A) receive a subsequent

measurement quantity within a predetermined time window; and B) associate the plurality of paths with the path group based at least in part on the subsequent measurement quantity.

[0277] In some implementations, the processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to transmit assistance information comprising an indication of a reflector entity associated with the path group. In such implementations, the report further comprises one or more of: A) an observed ToA spread associated with the reflector; B) an observed AoA spread associated with the reflector; or C) an observed ZoA spread associated with the reflector; or a combination thereof. In further implementations, the processor 1202 coupled with the memory 1204 may be configured to, capable of, or operable to cause the NE 1200 to determine positioning information associated with a sensing measurement node based at least in part on a location of the reflector entity and one or more of: the observed ToA spread, the observed AoA spread, or the observed ZoA spread, or a combination thereof.

[0278] In some implementations, the assistance information further comprises one or more properties of the reflector, including one or more of: A) a size of the reflector; B) a mobility pattern of the reflector; C) an expected ToA spread associated with the reflector; D) an expected AoA spread associated with the reflector; or E) an expected ZoA spread associated with the reflector; or a combination thereof. In one implementation, the assistance information may be included in the sensing configuration.

[0279] In some implementations, the one or more shared signaling path properties comprise one or more of: A) a path ToA for the path group; B) a path ToF for the path group; C) a path delay for the path group; D) a path AoA for the path group; E) a path ZoA for the path group; F) a path doppler shift for the path group; G) a path channel phase for the path group; or H) a RSRPP; or a combination thereof.

[0280] In certain implementations, the indication of the path group type comprises an index from a codebook (or table) of expected path group types. In certain implementations, the set of one or more measurement quantities associated with the path group is based on the path group type. In further implementations, the indication of a path group type may be an

implicit indication signaled by an inclusion in the report of one or more measurement quantities associated with the path group type.

[0281] In some implementations, the report further comprises an indication of the NF condition of a reflector object associated with the path group. In some implementations, the report further comprises an indication of a path group type based on the one or more shared signaling path properties. In such implementations, the one or more shared signaling path properties differ among the paths of the path group and satisfies a variation threshold. In one implementation, the variation threshold is a maximum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is less than the maximum variation. In another implementation, the variation threshold is a minimum variation, such that the variation threshold is satisfied when the differences in the shared signaling path property is greater than the minimum variation. In further implementations, the variation threshold may include both a maximum variation and a minimum variation.

[0282] In some implementations, the set of one or more measurement quantities associated with the path group comprises one or more of: A) an average ToA of the paths of the path group; B) a spread or variance of the ToA of the paths of the path group; C) an average ToF of the paths of the path group; D) a spread or variance of the ToF of the paths of the path group; E) an average delay of the paths of the path group; F) a spread or variance of the delay of the paths of the path group; G) an average AoA of the paths of the path group; H) a spread or variance of the AoA of the paths of the path group; I) an average ZoA of the paths of the path group; J) a spread or variance of the ZoA of the paths of the path group; K) an average doppler shift of the paths of the path group; L) a spread or variance of the doppler shift of the paths of the path group; M) an average channel phase of the paths of the path group; or N) a spread or variance of the channel phase of the paths of the path group; or a combination thereof.

[0283] The controller 1206 may manage input and output signals for the NE 1200. The controller 1206 may also manage peripherals not integrated into the NE 1200. In some implementations, the controller 1206 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 1206 may be implemented as part of the processor 1202.

[0284] In some implementations, the NE 1200 may include at least one transceiver 1208. In some other implementations, the NE 1200 may have more than one transceiver 1208. The transceiver 1208 may represent a wireless transceiver. The transceiver 1208 may include one or more receiver chains 1210, one or more transmitter chains 1212, or a combination thereof.

[0285] A receiver chain 1210 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1210 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 1210 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 1210 may include at least one demodulator configured to demodulate the received signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1210 may include at least one decoder for decoding/ processing the demodulated signal to receive the transmitted data.

[0286] A transmitter chain 1212 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1212 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 1212 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1212 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0287] **Figure 13** depicts one embodiment of a method 1300 in accordance with aspects of the present disclosure. In various embodiments, the operations of the method 1300 may be implemented by a UE or an NE (e.g., base station), as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions. In other implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0288] At step 1302, the method 1300 may include receiving one or more sensing signals. The operations of step 1302 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1302 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1302 may be performed by an NE, as described with reference to Figure 12.

[0289] At step 1304, the method 1300 may include performing a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration. The operations of step 1304 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1304 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1304 may be performed by an NE, as described with reference to Figure 12.

[0290] At step 1306, the method 1300 may include determining a path group based at least in part on the sensing procedure, wherein the path group comprises a plurality of paths associated with one or more shared signaling path properties. The operations of step 1306 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1306 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1306 may be performed by an NE, as described with reference to Figure 12.

[0291] At step 1308, the method 1300 may include transmitting a report comprising a set of one or more measurement quantities associated with the path group. The operations of step 1308 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1308 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1308 may be performed by an NE, as described with reference to Figure 12.

[0292] It should be noted that the method 1300 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0293] **Figure 14** depicts one embodiment of a method 1400 in accordance with aspects of the present disclosure. In various embodiments, the operations of the method 1400 may be implemented by a SensMF, such as the UE or NE or CN entity, as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions. In other implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0294] At step 1402, the method 1400 may include transmitting a sensing configuration for a sensing procedure, based on one or more sensing signals. The operations of step 1402 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1402 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1402 may be performed by an NE, as described with reference to Figure 12.

[0295] At step 1404, the method 1400 may include receiving a report comprising a set of one or more measurement quantities associated with a plurality of paths. The operations of step 1404 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1404 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1404 may be performed by an NE, as described with reference to Figure 12.

[0296] At step 1406, the method 1400 may include associating the plurality of paths with a path group, wherein the path group comprises a set of paths associated with one or more shared signaling path properties. The operations of step 1406 may be performed in accordance with examples as described herein. In some implementations, aspects of the operation of step 1406 may be performed by a UE, as described with reference to Figure 10. In other implementations, aspects of the operations of step 1406 may be performed by an NE, as described with reference to Figure 12.

[0297] It should be noted that the method 1400 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0298] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A radio node for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the radio node to:
receive one or more sensing signals;
perform a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration;
determine a path group based at least in part on the sensing procedure, wherein the path group comprises a plurality of paths associated with one or more shared signaling path properties; and
transmit a report comprising a set of one or more measurement quantities associated with the path group.

2. The radio node of claim 1, wherein the sensing configuration comprises at least one criteria for detection of the path group based on the one or more shared signaling path properties.

3. The radio node of claim 1, wherein the report further comprises:
an indication of the NF condition of a reflector object associated with the path group; or
an indication of a path group type based on the one or more shared signaling path properties,
wherein at least one property of the one or more shared signaling path properties differ among the paths of the path group and satisfies a variation threshold.

4. The radio node of claim 3, wherein the one or more shared signaling path properties comprise one or more of:
a path time-of-arrival (ToA) for the path group;

a path time-of-flight (ToF) for the path group;
a path delay for the path group;
a path angle-of-arrival (AoA) for the path group;
a path zenith-of-arrival (ZoA) for the path group;
a path doppler shift for the path group;
a path channel phase for the path group; or
a reference signal received path power (RSRPP);
or a combination thereof.

5. The radio node of claim 4, wherein the indication of the path group type comprises an index from a codebook of expected path group types.

6. The radio node of claim 4, wherein the set of one or more measurement quantities associated with the path group is based on the path group type, and wherein the indication of a path group type comprises an implicit indication signaled by an inclusion in the report of one or more measurement quantities associated with the path group type.

7. The radio node of claim 1, wherein the sensing procedure is further based on a near-field (NF) condition of one or more sensing signals observable at the radio node.

8. The radio node of claim 1, wherein the at least one processor is configured to cause the radio node to:
receive an indication of a time window associated with the sensing procedure;
determine the path group type based on the sensing procedure; and
transmit an indication of the path group type during the time window.

9. The radio node of claim 1, wherein the set of one or more measurement quantities associated with the path group comprises one or more of:
an average time-of-arrival (ToA) of the paths of the path group;
a spread or variance of the ToA of the paths of the path group;
an average time-of-flight (ToF) of the paths of the path group;
a spread or variance of the ToF of the paths of the path group;

an average delay of the paths of the path group;
a spread or variance of the delay of the paths of the path group;
an average angle-of-arrival (AoA) of the paths of the path group;
a spread or variance of the AoA of the paths of the path group;
an average zenith-of-arrival (ZoA) of the paths of the path group;
a spread or variance of the ZoA of the paths of the path group;
an average doppler shift of the paths of the path group;
a spread or variance of the doppler shift of the paths of the path group;
an average channel phase of the paths of the path group; or
a spread or variance of the channel phase of the paths of the path group;
or a combination thereof.

10. The radio node of claim 1, wherein the at least one processor is configured to cause the radio node to receive assistance information comprising an indication of a reflector entity associated with the path group.

11. A method performed by a radio node, the method comprising:
receiving one or more sensing signals;
performing a sensing procedure based at least in part on the one or more sensing signals and according to a sensing configuration;
determining a path group based at least in part on the sensing procedure, wherein the path group comprises a plurality of paths associated with one or more shared signaling path properties; and
transmitting a report comprising a set of one or more measurement quantities associated with the path group.

12. An apparatus comprising a sensing measurement function, the apparatus comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the sensing measurement function to:
transmit a sensing configuration for a sensing procedure, based on one or more sensing signals;

receive a report comprising a set of one or more measurement quantities associated with a plurality of paths; and

associate the plurality of paths with a path group, wherein the path group comprises a set of paths associated with one or more shared signaling path properties.

13. The apparatus of claim 12, wherein the at least one processor is configured to cause the sensing measurement function to:

receive a subsequent measurement quantity within a predetermined time window; and

associate the plurality of paths with the path group based at least in part on the subsequent measurement quantity.

14. The apparatus of claim 12, wherein the at least one processor is configured to cause the sensing measurement function to transmit assistance information comprising an indication of a reflector entity associated with the path group, and wherein the report further comprises one or more of:

an observed time-of-arrival (ToA) spread associated with the reflector;

an observed angle-of-arrival (AoA) spread associated with the reflector; or

an observed zenith-of-arrival (ZoA) spread associated with the reflector;

or a combination thereof.

15. The apparatus of claim 14, wherein the at least one processor is configured to cause the sensing measurement function to:

determine positioning information associated with a sensing measurement node based at least in part on a location of the reflector entity and one or more of:

the observed ToA spread,

the observed AoA spread, or

the observed ZoA spread,

or a combination thereof.

16. The apparatus of claim 12, wherein the assistance information further comprises one or more properties of the reflector, including one or more of:

a size of the reflector;

a mobility pattern of the reflector;

an expected time-of-arrival (ToA) spread associated with the reflector;

an expected angle-of-arrival (AoA) spread associated with the reflector; or

an expected zenith-of-arrival (ZoA) spread associated with the reflector;

or a combination thereof.

17. The apparatus of claim 12, wherein the sensing configuration comprises at least one criteria for detection of the path group based on the one or more shared signaling path properties.

18. The apparatus of claim 12, wherein the report further comprises an indication of the NF condition of a reflector object associated with the path group.

19. The apparatus of claim 12, wherein the report further comprises an indication of a path group type based on the one or more shared signaling path properties, wherein the one or more shared signaling path properties differ among the paths of the path group and satisfies a variation threshold.

20. A method performed by a sensing measurement function, the method comprising:

transmitting a sensing configuration for a sensing procedure, based on one or more sensing signals;

receiving a report comprising a set of one or more measurement quantities associated with a plurality of paths; and

associating the plurality of paths with a path group, wherein the path group comprises a set of paths associated with one or more shared signaling path properties.