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(54) Title: ENABLERS FOR SENSING ENTITY DISCOVERY AND SELECTION

(57) Abstract: A network node may receive sensing capability information associated with a plurality of sensing entities. The sensing capability information may include an indication of a respective sensing mode that is supported by each sensing entity. The network node may receive a sensing request that includes an indication of a sensing service requirement. The network node may select a plurality of candidate sensing entities from the plurality of sensing entities based on the sensing service requirement and/or the sensing capability information associated with each sensing entity of the plurality of sensing entities. The network node may receive respective sensing information from each of the plurality of candidate sensing information. The network node may select a subset of candidate sensing entities from the plurality of candidate sensing entities based on the respective sensing information from each of the plurality of candidate sensing entities. The network node may send a sensing response.



ENABLERS FOR SENSING ENTITY DISCOVERY AND SELECTION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to United States Provisional Patent Application No. 63/617,640 filed in the United States of America on January 4, 2024, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] RAN may refer to a radio access network based on the 5G RAT and/or Evolved E-UTRA that connects to the NextGen core network. The Access Control and Mobility Management Function (AMF) may include one or more of the following functionalities: Registration management, connection management, reachability management, mobility management, etc. The session management function (SMF) may include one or more of the following functionalities: session management (including session establishment, modify, and/or release), WTRU IP address allocation, selection, and/or control of UP function, etc. The User plane function (UPF) may include one or more of the following functionalities: packet routing and forwarding, packet inspection, traffic usage reporting, etc.

SUMMARY

[0003] A network node may receive sensing information associated with one or more sensing entities. The network node may receive the sensing information from an access and mobility management function and/or from a second network node. The sensing information may include one or more sensing capabilities and/or one or more sensing requirements. The network node may determine one or more candidate sensing entities of the one or more sensing entities based on the received sensing information. The network node may send a sensing requirement request to the one or more candidate sensing entities. The network node may receive a sensing requirement response from each of the one or more candidate sensing entities. The network node may determine one or more radio access network (RAN) nodes and/or one or more wireless transmit/receive units (WTRUs) based on the sensing information or the sensing requirement response from the one or more candidate sensing entities. The candidate sensing entities may include the one or more RAN nodes or the one or more WTRUs. The network node may send configuration information to the one or more RAN nodes and/or to the one or more WTRUs to configure the one or more RAN nodes and/or the one or more WTRUs based on the sensing information and/or the sensing requirement response from the one or more candidate

sensing entities. The network node may send a discover response to a second network node to update the sensing information associated with the one or more of: the one or more sensing entities, one or more candidate sensing entities, one or more RAN nodes, or one or more WTRUs.

[0004] A network node may receive a sensing service request from one or more of: one or more wireless transmit receive units (WTRUs) or one or more radio access network (RAN) nodes. The network node may determine authorization of the one or more WTRUs or the one or more RAN nodes. The network node may send a sensing capability message to a second network node. The sensing capability message may request sensing information of one or more sensing entities. The network node may receive a sensing capability response message. The sensing capability response message may include the sensing information of the one or more sensing entities. The sensing information may include one or more sensing capabilities and/or one or more sensing requirements. The network node may determine one or more candidate sensing entities based on the sensing information of the one or more sensing entities. The one or more sensing entities may include the one or more candidate sensing entities. The network node may send a sensing requirement request to the one or more candidate sensing entities. The network node may receive a sensing requirement response from each of the one or more candidate sensing entities. The network node may send a sensing response message to the one or more candidate sensing entities. The network node may send configuration information to one or more RANs and/or to one or more wireless transmit/receive units (WTRUs) to configure the one or more RAN nodes and/or the one or more WTRUs based on the sensing information and/or the sensing requirement response from the one or more candidate sensing entities.

[0005] The one or more sensing capabilities may include one or more of: data reporting frequency, sampling size of data, sensing mode, one or more supported sensing services, one or more 3GPP RAN sensing capabilities, one or more non-3GPP sensing capabilities, sensor output data type, type of sensing data processing, data compression capabilities, protocol information for sensing data and control data, network transmission information for sensing data and control data, sensing node role, authorization information, entity availability, entity utilization, time availability, and/or sensing area.

[0006] The one or more sensing requirements may include one or more requirements associated with one or more of: data time validity, one or more delay requirements; proximity, location of interest, sensing data communication preferences, periodicity, frequency, sampling size, time frame to perform a sensing task, or sensing speed.

[0007] A network node (e.g., sensing network function (NF)) may receive sensing capability information associated with a plurality of sensing entities. The sensing capability information may include an indication of a respective sensing mode that is supported by each sensing entity. The network node (e.g., sensing NF) may receive a sensing request. The sensing request may include an indication of a sensing service requirement. The network node (e.g., sensing NF) may select a plurality of candidate sensing entities from the plurality of sensing entities based on, for example, the sensing service requirement and/or the sensing capability information associated with each sensing entity of the plurality of sensing entities. The network node (e.g., sensing NF) may receive respective sensing information from each of the plurality of candidate sensing information. The sensing information may indicate a time that each candidate sensing entity of the plurality of candidate sensing entities is available to perform sensing and/or the respective sensing mode that is supported by each of the plurality of candidate sensing entities. The network node (e.g., sensing NF) may select a subset of candidate sensing entities from the plurality of candidate sensing entities based on the respective sensing information from each of the plurality of candidate sensing entities. The network node (e.g., sensing NF) may send a sensing response. The sensing response may indicate the subset of candidate sensing entities.

[0008] The sensing response may indicate the available time of each of the subset of sensing entities to perform the sensing. The sensing request may include a required sensing mode. The network node (e.g., sensing NF) may select the plurality of candidate sensing entities based on the required sensing mode. The sensing mode may be monostatic or bi-static.

[0009] The sensing capability information may include one or more of: a data reporting frequency, a sampling size, one or more supported sensing services, a sensor output data type, a type of sensing data processing, one or more data compression capabilities, protocol information for sensing data and control data, a sensing area, a sensing node role, authorization information, an entity availability, an entity utilization, and/or a network transmission information for sensing data and control data.

[0010] The sensing service requirement may include one or more of data time validity, one or more delay requirements, a proximity, a location of interest, one or more sensing data communication preferences, a data reporting frequency, a sampling size, a time frame, a sensing service, one or more quality of service (QoS) parameters, or a sensing speed.

[0011] The sensing capability information may be received from an access and mobility management function (AMF). The sensing capability information may include one or more of

sensing waveforms, a covered area, a maximum distance to a sensing target, and/or a maximum power used for sensing.

[0012] The network node may send configuration information to each sensing entity of the subset of candidate sensing entities. The configuration information may include sensing task information for each sensing entity of the subset of candidate sensing entities to perform a sensing task. The sensing task information may include a respective timer value, for each sensing entity of the subset of candidate sensing entities, to start performing the sensing task based on the respective timer value.

[0013] The subset of candidate sensing entities may include a first sensing entity and/or a second sensing entity. The sensing task information may include an indication that the first sensing entity is to communicate with the second sensing entity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] A more detailed understanding may be had from the detailed description below, given by way of example in conjunction with drawings appended hereto. Figures in such drawings, like the detailed description, are examples. As such, the Figures (FIGs.) and the detailed description are not to be considered limiting, and other equally effective examples are possible and likely. Furthermore, like reference numerals ("ref.") in the FIGs. indicate like elements, and wherein:

[0015] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented.

[0016] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment.

[0017] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment.

[0018] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment.

[0019] FIG. 2 depicts an example reference model of 5G/NextGen Network.

[0020] FIG. 3 depicts an example of pedestrian/animal intrusion detection.

[0021] FIG. 4 depicts an example intruder detection in surroundings of smart home.

[0022] FIG. 5 depicts an example of base station (BS) and/or wireless transmit/receive unit (WTRU) sensing objects.

[0023] FIGs. 6A and 6B depict a flow chart illustrating an example of exemplary procedures for an application function (AF) / network function (NF) initiated discovery.

[0024] FIGs. 7A, 7B, and 7C depict a flow chart illustrating an example WTRU/RAN initiated discovery.

[0025] FIGs. 8A and 8B depict a flow chart illustrating an example of sensor activation and/or operation management.

DETAILED DESCRIPTION

[0026] In the following detailed description, numerous specific details are set forth to provide a thorough understanding of embodiments and/or examples disclosed herein. However, it will be understood that such embodiments and examples may be practiced without some or all of the specific details set forth herein. In other instances, well-known methods, procedures, components and circuits have not been described in detail, so as not to obscure the following description. Further, embodiments and examples not specifically described herein may be practiced in lieu of, or in combination with, the embodiments and other examples described, disclosed or otherwise provided explicitly, implicitly and/or inherently (collectively "provided") herein. Although various embodiments are described and/or claimed herein in which an apparatus, system, device, etc. and/or any element thereof carries out an operation, process, algorithm, function, etc. and/or any portion thereof, it is to be understood that any embodiments described and/or claimed herein assume that any apparatus, system, device, etc. and/or any element thereof is configured to carry out any operation, process, algorithm, function, etc. and/or any portion thereof.

[0027] Example Communications System, Networks, and Devices

[0028] The methods, procedures, apparatuses and systems provided herein are well-suited for communications involving both wired and wireless networks. An overview of various types of wireless devices and infrastructure is provided with respect to FIGs. 1A-1D, where various elements of the network may utilize, perform, be arranged in accordance with and/or be adapted and/or configured for the methods, apparatuses and systems provided herein.

[0029] FIG. 1A is a diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable

multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word DFT-Spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0030] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a RAN 104/113, a CN 106/115, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a “station” and/or a “STA”, may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a WTRU.

[0031] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the CN 106/115, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a gNB, a NR NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0032] The base station 114a may be part of the RAN 104/113, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0033] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0034] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104/113 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 115/116/117 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed UL Packet Access (HSUPA).

[0035] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0036] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using New Radio (NR).

[0037] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., a eNB and a gNB).

[0038] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi)), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0039] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106/115.

[0040] The RAN 104/113 may be in communication with the CN 106/115, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106/115 may provide call control,

billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing a NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0041] The CN 106/115 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104/113 or a different RAT.

[0042] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0043] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0044] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller,

Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0045] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0046] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0047] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0048] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage

device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0049] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0050] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0051] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors, the sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor; an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, and/or a humidity sensor.

[0052] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and downlink (e.g., for reception) may be concurrent and/or simultaneous. The full

duplex radio may include an interference management unit 139 to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WRTU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the downlink (e.g., for reception)).

[0053] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0054] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a.

[0055] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0056] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (or PGW) 166. While each of the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0057] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0058] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets

to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0059] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0060] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0061] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0062] In representative embodiments, the other network 112 may be a WLAN.

[0063] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have an access or an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an “ad-hoc” mode of communication.

[0064] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0065] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0066] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0067] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications, such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0068] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode), transmitting to the AP, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0069] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0070] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0071] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated

Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0072] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0073] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0074] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0075] The CN 115 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN) 185a, 185b. While each of the foregoing elements are depicted as part of

the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0076] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different PDU sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for machine type communication (MTC) access, and/or the like. The AMF 162 may provide a control plane function for switching between the RAN 113 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0077] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating WTRU IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0078] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering downlink packets, providing mobility anchoring, and the like.

[0079] The CN 115 may facilitate communications with other networks. For example, the CN 115 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 115 and the PSTN 108. In addition, the CN 115 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112,

which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local Data Network (DN) 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0080] In view of Figures 1A-1D, and the corresponding description of Figures 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-ab, UPF 184a-b, SMF 183a-b, DN 185a-b, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0081] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or may performing testing using over-the-air wireless communications.

[0082] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0083] Embodiments are described herein for an application function (AF)/network function (NF) initiated discovery procedure. The WTRU may register with 5G Core (5GC) with its sensing capabilities. The RAN nodes may register with the 5GC with sensing capabilities. Sensing may be triggered at a NF/AF and/or at an application server (AS), and may request for available sensing entities from a sensing NF, and/or may request sensing/discovery service from the

sensing NF. This may include the sensing area, sensing mode, and/or one or more properties of the sensing target. The sensing NF may obtain information of available sensing WTRUs and/or RAN nodes from a NF (e.g., access control and mobility management function (AMF)), including their supported modes of operation (e.g., bi static, monostatic) of each entity. The sensing NF may select one or more (e.g., relevant) WTRUs and/or RAN sensing entities. The Sensing NF may obtain sensing information from the one or more (e.g., relevant) RAN nodes and/or WTRUs. For example, the sensing NF may obtain sensing information from the one or more RAN nodes and/or WTRUs in a sensing request message, which then the entities may accept/reject. The sensing NF may select (e.g., suitable) entities and/or may send them to the initiating NF/AF/AS in a sensing service/discovery response message. The sensing server may update local database(s) and/or may send in a message the information of one or more available sensing entities. The NF and/or AF may configure the selected WTRU and/or the one or more RAN nodes for a sensing task. The WTRU and/or the one more RAN nodes that are involved in the task may calibrate and/or update one or more configurations for sensing (e.g., through communicating directly). The WTRU and/or the RAN entities may perform the sensing task.

[0084] Embodiments are described herein for WTRU and/or RAN initiated discovery. The WTRU) and/or the RAN nodes may register (e.g., via WTRU registration, registration over N2) their respective sensing capabilities. Sensing may be triggered at the WTRU and/or the RAN node (e.g., when sensing data consumed at the RAN), and/or may request for sensing services and/or available sensing entities from the sensing NF. This request may include a discover criteria / sensing requirements (e.g., location, preferred distance to the sensing target, sensing area, sensing mode, etc.). The sensing NF may authorize the received request, as described herein, for sensing (e.g., with unified data management (UDM)). The sensing NF may obtain information of available sensing entities from the NF, including the mode of operation of each entity. The sensing NF may send sensing requests to the WTRU and/or RAN entities, for obtaining their availability for a sensing task. This message may be a sensing request, which (e.g., then) the entities may accept / reject. The sensing NF may select (e.g., suitable) entities and/or may respond to the WTRU and/or the RAN. The sensing response may include one or more configurations (e.g., required configurations) for connecting with the sensing entities. In examples, if one or more (e.g., multiple) sensing candidates are received, as described herein, the WTRU and/or the RAN entity(ies) may select the (e.g., suitable) sensing entities. The WTRU and/or RAN node entity may send a configuration update message to the sensing NF with the selected sensing entities and/or their configurations. In examples, the sensing NF may select

the (e.g., suitable) sensing entities. The WTRU and/or the RAN nodes may update their sensing configurations (e.g., establish sender and/or receiver role configurations in bi-static sensing). The WTRU and RAN nodes may exchange sensing data.

[0085] Embodiments are described herein with respect to sensor activation and/or operation management. The WTRU and/or RAN sensing entities may register their capabilities (e.g., with the 5GC). This may be through WTRU registration procedures and/or N2 RAN node registration procedures. One or more sensor nodes may be configured for sensing and/or may start the sensing task. A change in context may be detected (e.g., by the WTRU and/or the RAN nodes). This may be a change in the environment and/or to the network. For example, the change in distance to the target object may change, due to user's mobility and/or due to the object's mobility. The WTRUs (e.g., over N1) and/or RAN (e.g., over N2) nodes may report the one or more changes in context to the 5GC (e.g., sensing NF). For example, this may include distance to the target WTRU, network conditions, and/or WTRU mobility status. The sensing NF may obtain information of available RAN and/or WTRU sensing entities. For example, the sensing NF may obtain information of available RAN and/or WTRU sensing entities through communicating with the AMF. The sensing NF may discover one or more other (e.g., new) RAN and/or WTRU sensing entities (E.g., using solution 1). In examples, the sensing entity may discover one or more other (e.g., new) RAN and/or WTRU sensing entities after determining to activate one or more other (e.g., new) sensing entities (e.g., to extend coverage). The sensing NF may determine the sensor activation/deactivation strategy, deciding on which sensors to be activated and deactivated. If the Sensing NF determines to deactivate one or more sensing entities, the sensing NF may send a deactivation message to the one or more sensing entities. For example, a first WTRU and/or a first RAN node may receive a deactivation message from the 5GC (e.g., sensing NF). This message may specify a timer for deactivating the sensor and/or another timer for keeping the sensor deactivated. The first WTRU and/or first RAN node may deactivate the sensor. If the Sensing NF determines to activate one or more sensing entities, the sensing NF may send an activation message to the one or more sensing entities. For example, a third WTRU and/or a third RAN node may receive an activation message from the 5GC (e.g., sensing NF). This message may specify a timer for activating the sensor and/or another timer for keeping the sensor activate. The third WTRU and/or third RAN node may activate the sensor. Additionally or alternatively, one or more sensing entities may receive a message from the 5GC indicting that the sensor continue to be activated. For example, the third WTRU and/or the third RAN may receive a message from the 5GC (e.g., sensing NF) indicating that the sensor to continue to be activated.

[0086] FIG. 2 depicts a reference model 200 of a potential architecture of 5G and/or Next Generation networks. RAN may refer to a radio access network based on the 5G RAT and/or Evolved E-UTRA that connects to the NextGen core network. The Access Control and Mobility Management Function (AMF) may include one or more of the following functionalities: Registration management, connection management, reachability management, mobility management, etc. The session management function (SMF) may include one or more of the following functionalities: session management (including session establishment, modify, and/or release), WTRU IP address allocation, selection, and/or control of UP function, etc. The User plane function (UPF) may include one or more of the following functionalities: packet routing and forwarding, packet inspection, traffic usage reporting, etc.

[0087] Sensors may generate data as a result of sensing the physical phenomenon (e.g., light, heat, motion, speed). Sensors may be designed for sensing one or more (e.g., various) properties of the environment / target object. For example, a photoelectric sensor may detect one or more objects and/or changes in surface conditions. There may be passive and/or active sensors. For example, active motion sensors emit signals (e.g., such as a laser) and/or may detect the one or more changes in the reflected signal. For example, passive infrared sensors (PIR) may detect infrared radiation emitted by and/or reflected from one or more objects. Sensors may differ, for example, depending on the electromagnetic waves being used for sensing. In contrast to the example on IR sensing, as described herein, radio frequency (RF) sensors may utilize radio waves to detect physical phenomenon through detecting its frequency responses. Such sensing capabilities may be built into existing RF devices, such as mobile devices and/or cellular base stations.

[0088] Integrated sensing may include one or more use cases and/or potential requirements for enhancement of (e.g., 5G) system(s) to provide sensing services addressing different target verticals/applications (e.g., autonomous/assisted driving, V2X, UAVs, 3D map, smart city, smart home, factories, healthcare, maritime sector, etc.). For integrated sensing, there may be a process of collecting sensing measurement data which is data collected about radio/wireless signals impacted (e.g., reflected, refracted, diffracted) by an object and/or environment of interest for sensing purposes and/or may derive sensing results from processing sensing measurement data. And, there may be an area defined for sensing (e.g., sensing service area location), which is an area location whether with or without obstacle, the 5G system can provide sensing service with certain quality. One or more other N3GPP entities may be considered. The sensing measurement data of the one or more other N3GPP entities may be considered as

transparent to 5G system (5GS) such that the data of the one or more other N3GPP entities may be communicated using a standard protocol to an interference defined by the 5GS.

[0089] FIGs. 3 and 4 depict example use cases for integrated sensing for object detection. FIG. 3 depicts an example illustration of pedestrian/animal intrusion detection 300 (e.g., on a highway). FIG. 4 depicts an example illustration 400 of intruder detection in surroundings of a smart home. The base station and/or WTRU may detect the intrusion on the sensing area of a base station by itself and/or by collaboration between the WTRU and the base station. The sensing measurement may be transferred to the network and/or further processed into the sensing result.

[0090] FIG. 5 depicts an example of base station (BS) and/or WTRU sensing objects 500. FIG. 5 illustrates another use case for integrated sensing with respect to transparent sensing in which sensing data may be captured by the WTRU and communicated so that the 5GS is aware of the sensing information. The user terminal may acquire sense signals from one or more (e.g., many) 3GPP and/or non-3GPP devices. The 5GC may determine one or more (e.g., various) available sensing services, for example, by processing collated sensing data.

[0091] For example, base station (BS) may send a dedicated signal for sensing a target object (target 1, ..., or, target K). WTRUs may be coordinated to receive the dedicated signal for sensing which is sent from base station (BS). Each WTRU may send a message for the received signal to the BS over the communication signal. The message may include different radio characteristics from original signal from BS. After collocating the received signal from each WTRU, the BS may identify an object based on the received different radio characteristics.

[0092] Sensing operation types may be provided herein. One type of sensing operation type may be monostatic sensing. Monostatic sensing may be from radar like sensing where the sensing transmitter and sensing receiver are co-located in the same entity. Another type of operation type may be bistatic sensing, where the sensing receiver and the sensing transmitter are in different entities. Multistatic sensing operation type may include one or more (e.g., multiple) sensing transmitters and/or receivers.

[0093] One or more requirements may be described herein with respect to sensing. The 5G system may provide 5G wireless sensing service in a target sensing service area location using sensing transmitters and/or sensing receivers. Subject to regulation and/or operator policy, the 5G network may activate, configure, and/or deactivate 5G wireless sensing based on parameters such as location and/or network conditions (e.g., network load).

[0094] The 3GPP system may not enable the discovery and/or selection of sensing entities within a specific target sensing service area, that satisfy the requirements of a sensing task. The

discovery and/or selection procedures may distinguish the sensors whose sensing transmitter and sensing receiver are co-located in the same entity (e.g., monostatic sensing), and/or the entities where the sensing receiver and sensing transmitter are in one or more different entities (bistatic sensing). When determining sensing mechanism, for example, a network (NW) entity may be aware of availability of WTRUs for sensing when the WTRU and/or NW entities may be involved for sensing. How the NW may be aware of this availability may be described herein.

[0095] For coordination of sensing operation, the NW may determine the list of WTRUs and/or NW entities for sensing involved. How the NW can discover and/or select those entities may be addressed herein.

[0096] Transmission of sensing signals may consume more energy than receiving. A sensing entity may choose the type of sensing mode, for example, based on one or more parameters, such as available power and/or the distance to the sensing target. Once discovered, the existing procedures may not enable sensing entities to be activated, configured, and/or deactivated based on one or more parameters, such as location, target sensing object's and/or user's mobility and/or one or more network conditions.

[0097] How to discover sensors while considering different sensing operation modes, distinguishing the sensors whose sensing transmitter and/or sensing receiver are co-located in the same entity (e.g., monostatic sensing), and/or the entities where the sensing receiver and sensing transmitter are in one or more different entities (e.g., bistatic) may be addressed herein. Once discovered, how to account for one or more (e.g., various) contextual changes (e.g., in the sensing target, sensors, and/or the network), allowing sensing entities to be interchanged, activated, and/or deactivated while ensuring that sensing requirements are met, may be addressed herein.

[0098] Sensing Network Functions (Sensing NF) may be another network function that provides integrated sensing. Sensing NF may refer to Integrated Sensing Assistance NF (ISANF) and/or Sensing Operation Management Function (SOMF). ISANF and/or SOMF may be logical entities and/or may be collocated with one or more other entities (e.g., ISANF may be collocated with a network exposure function (NEF), ISANF and SOMF may both be collocated with NEF, SOMF may collocate with AMF, and/or SOMF may collocate with RAN).

[0099] The ISANF may oversee interaction with the application function for sensing service. The ISANF may understand the service request from the Application Function (AF) and/or can derive corresponding requested sensing mechanism(s). Based on the sensing mechanism, for example, the ISANF may forward the request to the relevant NFs within the 5GC, which may serve the region of interest and/or requested entities such as WTRUs. When the application

function is a third party application, which may not be a trusted entity of 5GS, for example, the application function and the ISANF may communicate through a NEF.

[0100] The SOMF may handle coordination of sensing operation among one or more network entities (e.g., the BS and/or one or more WTRUs). Based on information received from the AMF, for example, the SOMF may derive coordination information for sensing operation. Information received from the AMF may include one or more of: requested sensing region, BS's and/or WTRU's list, and/or requested sensing mechanism with Quality of Service (QoS) requirement(s). For example, the SOMF may decide the role of sensing operation such as sender(s) of sensing signal(s), receiver(s) of sensing signal(s), entity to collect the sensing measurement data, entity to calculate sensing result, etc. For example, the SOMF may decide sensing period, the waveform of sensing signal and/or may ask the BS(s) and/or sender(s) resource assignment for sending sensing signal at the sensing period.

[0101] A sensing task may be a process where one or more sensors (e.g., RF, video, audio, motion) are used for generating data about the environment (e.g., a target object, a user). These data may be consumed and/or stored by the WTRU, the 5GS, an application, and/or one or more (e.g., any) other networked entity. The 5GS system may provide means to manage the sensors and/or sensing entities, process sensing data, communicate sensing data and results from the sensing entities to respective destination/data consumers (e.g., WTRU, NF, AF, RAN).

[0102] One or more procedures described herein may include one or more (e.g., various) sensing related capability parameters. Sensing capabilities may include periodicity/frequency with respect to data reporting frequency. Sensing capabilities may include sampling size (e.g., sampling size of data). Sensing capabilities may include sensing mode (e.g., monostatic sensing, bistatic sensing). Sensing capabilities may include one or more supported sensing services. Sensing capabilities may include one or more 3GPP RAN sensing capabilities (e.g., gNB). Sensing capabilities may include one or more non-3GPP sensing capabilities (e.g., lidar, Wifi, etc.). Sensing capabilities may include sensor output data type (e.g., raw). Sensing capabilities may include type of sensing data processing (e.g., anonymization). Sensing capabilities may include one or more data compression capabilities. Sensing capabilities may include protocol information for sensing data and/or control data (e.g., UDP for sensing data, TCP for control/meta data). Sensing capabilities may include network transmission information for sensing data and/or control data (e.g., 3GPP Uu for Control data, and/or data plane for sensing data). Sensing capabilities may include one or more other data processing and/or analytics capabilities (e.g., object detection). Sensing capabilities may include sensing node role (e.g., data consumer, data provider, service provider, service consumer, etc.). Sensing

capabilities may include authorization information. Authorization information may include information per sensing role. For example, each sensing role may be (e.g., required to be) authorized separately. Sensing capabilities may include entity availability and/or utilization (e.g., indication of how many other sensing tasks are performed by the WTRU, how many other and/or new sensing tasks may be accepted by the RAN node, level of priority the RAN node can give to new tasks, etc.) For example, at a given time there may be (e.g., only) one high priority sensing task. Sensing capabilities may include time availability (e.g., specifies the time duration a sensor may provide its capability(ies) to a task). For example, resource scarce sensors may not provide its services for a long period of time for a single task. Sensing capabilities may include sensing area (e.g., specifies the location and/or area covered for sensing by the sensor).

[0103] One or more procedures described herein may include one or more (e.g., various) sensing related requirement parameters (e.g., in the one or more messages). For example, such requirement(s) may be included as discovery criteria, discovery requirements, and/or sensing requirements. One or more procedures described herein may include one or more (e.g., various) sensing related requirements. Sensing requirements may be associated with data time validity (e.g., time a portion of data valid for). Sensing requirements may be associated with one or more delay requirements (e.g., minimum delay may be met for transmitting sensing data). Sensing requirements may be associated with one or more proximity requirements. For example, sensing one or more proximity requirements may be associated with the proximity to the sensing target (e.g., user and/or an object). Sensing requirements may be associated with location of interest (e.g., location of the target object (if known)). Sensing requirements may be associated with sensing data communication preferences (e.g., control plane, user plane, sidelink, Uu, etc.). Sensing data communication preferences may specify how sensing data and/or control data is transferred. For example, this may specify that control data may be transferred over the control plane, while the sensing data are sent through the data plane. Sensing requirements may be associated with periodicity/frequency (e.g., data reporting frequency). Sensing requirements may be associated with sampling size (e.g., sampling size of the data). Sensing requirements may be associated with time frame the sensing task may be performed. For example, the time frame may be specified as one or more (e.g., any) combinations of an exact time window during the day (e.g., 09:00-10:00), as a duration, a start/end time, and/or a timer. Sensing requirements may be associated with sensing speed. Sensing speed may include how fast the sensor may capture (e.g., all required) information. For example, one or more (e.g., some) sensors may be faster than one or more other sensors.

[0104] Embodiments may be described herein for AF/NF initiated discovery.

[0105] FIGs. 6A and 6B depict a flowchart illustrating an exemplary procedure for AF/NF initiated discovery 600, 650.

[0106] At 614, the WTRU(s) 602 may register with the 5GS. The WTRU 602 may provide its sensing capability(ies), as described herein, to the 5GS. For example, the sensing capability information may include one or more of: a data reporting frequency, a sampling size, one or more supported sensing services, a sensor output data type, a type of sensing data processing, one or more data compression capabilities, protocol information for sensing data and control data, a sensing area, a sensing node role, authorization information, an entity availability, an entity utilization, or a network transmission information for sensing data and control data. The 5GS (e.g., AMF 06) may store these for future use. The WTRU 602 may be authorized for sensing. The authorization may be for one or more (e.g., any) of the capability parameters, as described herein. Registration may be performed through one or more means. For example, registration may be through WTRU registration procedures, and/or may be provided by a NF (e.g., 610, 612) and/or an AF 612 (e.g., via the NEF). Registration may be through one or more other control signaling and/or periodic and/or event based reporting.

[0107] At 616, the one or more RAN nodes (e.g., 604) may register with the 5GS. The one or more RAN nodes may provide its sensing capability(ies), as described herein, to the 5GS, and/or the 5GS (e.g., AMF) may store the sensing capabilities of each respective RAN nodes 604 for (e.g., future) use. For example, sensing capabilities may relate to supported sensing modes (e.g., monostatic, bi-static), sensing waveforms, covered area, maximum distance to sensing target, and/or maximum power used for sensing. RAN node registration and/or initialization may indicate if the sensing can be used for optimizing the network. For example, it may specify that sensing data may be used for improving the beamforming efficiency. The RAN node may (e.g., subsequently) register as a sensing data consumer. It may also specify which data streams, quality of service (QoS) flow and/or control plane data (e.g., when sensing results are sent over the control plane) may be consumed. The procedures at 614 and/or at 616 may be used for registering and/or gathering the total available capabilities.

[0108] At 618, the AMF 606 may update its local database of RAN node capabilities.

[0109] At 620, the sensing NF 608 may receive a message from the AMF 606 with the information of the newly registered RAN node and/or WTRUs. This message may include information received by the AMF 606 from the RAN node 604. This message may include information related to neighboring RAN nodes. This information may be used by the sensing NF 608, for example, when selecting (e.g., suitable) sensing entities. This may include the one or more acquired capabilities of the WTRU 602, as described herein. For example, the network

node (e.g., sensing NF 608) may receive sensing capability information associated with a plurality of sensing entities. The sensing capability information may include an indication of a respective sensing mode that is supported by each sensing entity. The sensing capability information may be received from an access and mobility management function (AMF) 606. The sensing capability information may include one or more of sensing waveforms, a covered area, and/or a maximum power used for sensing. For example, the sensing capability information may include one or more of: a data reporting frequency, a sampling size, one or more supported sensing services, a sensor output data type, a type of sensing data processing, one or more data compression capabilities, protocol information for sensing data and control data, a sensing area, a sensing node role, authorization information, an entity availability, an entity utilization, or a network transmission information for sensing data and control data.

[0110] At 622, a sensing task may be triggered at a NF 612, an AF 612, and/or an application server (AS) 612. An example of such a trigger may be an application that may require to generate a real-time map of user's environment (e.g., RF environment mapping) and/or may require additional information from the network. In examples, a NF may determine that sensing data is included (e.g., needed) for optimizing the network resources (e.g., beam management and mobility enhancements).

[0111] At 624, the NF/AF/AS 612 may send a sensing request to the NF/NEF 610. For example, when AF/AS 612 is a third party entity, the AF/AS 612 can communicate with the (e.g., 5G) system (e.g., only) via NEF. The sensing request may be a sensing entity discovery message and/or a sensing service request. The sensing request may include one or more requirement parameters specifying the one or more requirements of the request, as described herein. The NF/NEF 610 may send the sensing request to the sensing NF 608. In examples, the NF/AF/AS 612 may send the sensing request to the sensing NF 608 (e.g., directly).

[0112] At 626, the sensing NF 608 may receive a sensing request from a NF 612, AF 612, and/or an AS 612. The sensing request may be a sensing entity discovery message and/or a sensing service request. This message may include one or more requirement parameters specifying the one or more requirements of the request, as described herein. For example, a network node (e.g., sensing NF 608) may receive a sensing request. The sensing request may include an indication of a sensing service requirement. The sensing service requirement may include one or more of data time validity, one or more delay requirements, a proximity, a location of interest, one or more sensing data communication preferences, a data reporting frequency, a sampling size, a time frame, a sensing service, one or more quality of service (QoS) parameters, or a sensing speed. The sensing request may include a required sensing

mode. The network node (e.g., sensing NF 608) may select the plurality of candidate sensing entities based on the required sensing mode.

[0113] At 628, the sensing NF 608 may obtain information of one or more potential (e.g., candidate) sensing entities. This information may include information of WTRUs 602 and/or information of RAN nodes 604. The sensing NF 608 may communicate with the AMF 606 for obtaining information of the WTRUs 602 and/or the RAN nodes 604. The sensing NF 608 may obtain this information from a local stored database and/or through querying another NF and/or the sensing entities. Additionally or alternatively, the sensing NF 608 may receive such information from capability reports received from the sensing entities.

[0114] At 630, the sensing NF 608 may select one or more (e.g., most) suitable sensing entities and/or their sensing modes, that satisfy the one or more requirements of the sensing task, that may be used. For example, the network node (e.g., sensing NF 608) may select a plurality of candidate sensing entities from the plurality of sensing entities based on the sensing service requirement and/or the sensing capability information associated with each sensing entity of the plurality of sensing entities.

[0115] The sensing NF 608 may send one or more requests to the selected/shortlisted (e.g., candidate) sensing entities to request for the specific sensing services and/or capabilities for the (e.g., sensing) task. For example, specific sensing services and/or capabilities may include sensing signal receiving capabilities (e.g., frequency and/or channel) from the sensing transmission entities. The one or more sensing entities may accept or reject the request (e.g., a RAN node may reject the request when it is not able to commit resources to this task). The information in the one or more requests here may differ than the information at procedures 614 and/or 616. One or more procedures may be used for allowing one or more sensing entities to accept or reject the specific task (e.g., in the sensing report) and/or reserve and/or allocate one or more resources to this specific task. In examples, where one or more resources are reserved, it may specify the time it may be reserved for. The sensing NF 608 may select the (e.g., suitable) sensing entities (e.g., as opposed to potentially suitable sensing entities), for example, after (e.g., only after) gathering the information herein.

[0116] At 632, the sensing NF 608 may send a sensing request to one or more RAN nodes 604 selected for the task. This message may include sensing requirement(s), described herein, chosen for the sensing entity. This message may include the (e.g., respective) sensing mode chosen for this sensing entity. The sensing mode may be monostatic and/or bi-static. This procedure may negotiate which entities, and/or the type of entity(ies), the sensing data may directly be provided to. For example, in one or more (e.g., some) sensing scenarios, complete

and/or partial sensing data may (e.g., need to) be provided to the WTRU for deriving the sensing result.

[0117] At 634, the sensing NF 608 may receive a response from the (e.g., respective) RAN node(s) 604. This message may indicate whether the sensing request is accepted or rejected. This message may include one or more sensing capabilities, as described herein, that may be offered to this sensing task.

[0118] At 636, the sensing NF 608 may send a sensing request to one or more (e.g., candidate) WTRUs (e.g., 602) selected for the sensing task. This message may include one or more sensing requirements, as described herein, chosen for this sensing entity. This message may include the sensing mode chosen for this sensing entity.

[0119] At 638, the sensing NF 608 may receive a response from the one or more (e.g., respective) WTRUs (e.g., 602). This message may indicate whether the sensing request is accepted or rejected. This message may include one or more sensing capabilities, as described herein, that may be offered to this sensing task. This message may be a discover response including one or more discovered sensing entities. For example, the network node (e.g., sensing NF 608) may receive respective sensing information from each of the plurality of candidate sensing entities. The sensing information may indicate a time that each candidate entity of the plurality of candidate sensing entities is available to perform sensing and/or the respective sensing mode that is supported by each of the plurality of candidate sensing entities. The sensing response may indicate the available time of each of the subset of sensing entities to perform the sensing. The sensing entity may accept or reject the sensing request based on the available time of the sensing entity to perform the sensing.

[0120] At 640, the sensing NF 608 may select the one or more sensing entities for the sensing task. For example, the sensing NF 608 may select the one or more sensing based on the one or more responses received for the sensing requests to the WTRUs 602 and/or the RAN nodes 604. If the sensing NF 608 determines that the response(s) are not satisfactory, the sensing NF 608 may perform procedures 630-638 until satisfied. For example, when the number of received response from WTRUs are less than the number of WTRUs for providing sensing operation with requested sensing service quality or for sensing operation with specific sensing operation mode, the sensing NF 608 may perform procedure 630-638 (e.g., again). The sensing NF 608 may select the one or more (e.g., suitable) sensing entities (e.g., only) after gathering this information. For example, a network node (e.g., sensing NF 608) may select a subset of candidate sensing entities from the plurality of candidate sensing entities based on the respective sensing information (e.g., supported sensing mode, supported service quality of the

supported sensing mode such as granularity, sensitivity, etc.) from each of the plurality of candidate sensing entities.

[0121] At 642, the sensing NF 608 may send a response message to the NF 612, the AF 612, and/or the AS 612 that sent the request. The response message may include the information of the sensing capability(ies) offered by the network. This message may include information of sensing entities selected for the sensing task, and/or their capabilities (e.g., as described herein). For example, the network node (e.g., sensing NF 608) may send a sensing response. The sensing response may indicate the subset of candidate sensing entities.

[0122] At 644, the initiating NF 612, AF 612, and/or AS 612 may update the received information of one or more sensing entities in a local database. This message may indicate when the sensing task may be initiated. If the sensing task is to be initiated by the sensing NF 608 (or one or more (e.g., any) other NF), it may indicate its status (e.g., already requested, to be requested in time T, pending, etc.).

[0123] One or more procedures may be used for configuring and/or initializing and/or starting the sensing task, once the one or more entities are discovered.

[0124] At 646, the one or more sensing entities may be configured for the sensing task, and/or the task may get initiated. Depending on the configuration, for example, one or more of the following entities may trigger configuration and/or initiation. The sensing NF 608 may trigger this procedure and/or may inform the initiating NF/AF/AS of its status in a message. The initiating NF/AF/AS 612 may send a message to the sensing NF 608 indicating that the sensing entity(ies) are to be configured and/or initiated.

[0125] The sensing NF 608 may send configuration and/or initiation messages to the chosen sensing entity(ies). The configuration may include one or more (e.g., any) of the parameters, as described herein, to be used for this task. The sensing entity(ies) may receive an indication of when to start the sensing task. For example, this indication may be specified as a timer value. The sensing NF 608 may specify if (e.g., further) configuration may be required. For example, one or more sensing entities may (e.g., be required to) communicate with each other for calibrating its parameters (e.g., parameters related to bi-static receiver and/or sender, and/or initialize parameters related to connectivity to be established for sharing sensing data and/or results). The network node (e.g., sensing NF 608) may send configuration information to each sensing entity of the subset of candidate sensing entities. The configuration information may include sensing task information for each sensing entity of the subset of candidate sensing entities to perform a sensing task. The sensing task information may include a respective timer value, for each sensing entity of the subset of candidate sensing entities, to start performing the

sensing task based on the respective timer value. The subset of candidate sensing entities may include a first sensing entity and/or a second sensing entity. The sensing task information may include an indication that the first sensing entity is to communicate with the second sensing entity.

[0126] At 648, the one or more configured sensing entities may communicate with each other for updating their configuration. These may be RRC configurations.

[0127] At 650, the configured sensing entities may start sensing. For example, the configured sensing entities may start sensing based on the sensing task information received (e.g., as described herein).

[0128] Embodiments are provided herein with respect to WTRU and/or RAN initiated discovery.

[0129] FIGs. 7A, 7B, and 7C depict a flowchart illustrating an example WTRU/RAN initiated discovery 700, 725, 775.

[0130] At 716, the one or more RAN and/or WTRU sensing entities 702 may register with the 5G system. The WTRU and/or RAN capabilities may be received by the NF 712 and/or managed by it (e.g., AMF 706). The capabilities associated with each candidate sensing entity may include an indication of a respective sensing mode. The WTRU 702 may be configured to select the one or more sensing entities based on one or more of: the respective sensing mode, the one or more requirement parameters, and/or the sensing time frame associated with performing the sensing task. The one or more capabilities may include one or more of: a data reporting frequency, a sampling size, one or more supported sensing services, a sensor output data type, a type of sensing data processing, one or more data compression capabilities, protocol information for sensing data and control data, a sensing area, a sensing node role, authorization information, an entity availability, an entity utilization, or a network transmission information for sensing data and control data.

[0131] At 718, a sensing task may be triggered at a WTRU 702 and/or a RAN node 702. An example of such a trigger at the WTRU 702 may be an application that requires to generate a real-time map of a user's environment (e.g., RF environment mapping) and/or may (e.g., require) include additional information from the network (e.g., beam management and/or one or more mobility enhancements). An example of such a trigger at the RAN node 702 may be resource monitoring in RAN determines that sensing data is included (e.g., needed) for optimizing the network resource(s). For example, the WTRU 702 may determine that a sensing task is triggered. The WTRU 702 may determine that the sensing task is triggered based on an application running on the WTRU 702 requesting a real-time map of an environment of the WTRU 702.

[0132] At 720, a WTRU 702 and/or RAN node 704 may send a sensing service / discover request to the sensing NF 710, via the AMF 706. This message may be a sensing entity discovery message and/or a sensing service request. This message may include one or more requirement parameters, as described herein, specifying the requirement(s) of the request. For example, this may include (e.g., required) authorization token(s). This message may include the sensing time frame that the sensing operation may be performed. The WTRU 702 may send a sensing request. The sensing request may indicate one or more requirement parameters, a sensing mode associated with a sensing task, and/or a sensing time frame associated with performing the sensing task. The one or more requirement parameters may include one or more of: one or more authorization tokens, one or more of data time validity, one or more delay requirements, a proximity, a location of interest, one or more sensing data communication preferences, a data reporting frequency, a sampling size, a time frame, a sensing service, one or more quality of service (QoS) parameters, or a sensing speed.

[0133] At 722, the sensing NF 710 and/or the AMF 706 may authorize the requesting entity. For example, the sensing NF 710 and/or the AMF 706 may authorize the requesting entity to ensure that it is authorized to receive one or more sensing services. The authorization token may be validated and/or the sensing NF 710 and/or the AMF 706 may communicate with the UDM 714 for authorization.

[0134] At 724, the sensing NF 710 may request information of potential (e.g., candidate) sensing entities by communicating with a NF 712 (e.g., AMF 706, NEF, and/or other NF). This procedure may include one or more sensing task requirements, as described herein (e.g., location of the target object and/or the sensing area).

[0135] At 726, the sensing NF 710 may receive a sensing capability response message from the NF 712. This message may include a list of available entities (e.g., WTRUs 702 and/or RAN nodes 702), with their capability parameters, as described herein. Information received in procedures 716, 720, 724, and/or 726 may be used for registering the gathering available capabilities.

[0136] At 728, the sensing NF 710 may select one or more potential (e.g., candidate) sensing entities and/or their sensing modes that satisfy the one or more requirements of the sensing task.

[0137] The sensing NF 710 may send one or more requests to the capabilities selected/shortlisted sensing entities, request for the specific sensing services / capabilities (e.g., needed) for the task. For example, the sensing NF 710 may request sensing signal receiving capabilities (e.g., frequency, channel, etc.) from the sensing receiver entities and/or sensing

signal transmission capabilities (e.g., frequency, channel, etc.) from the sensing signal transmission entities. One or more sensing entities may accept or reject the request. For example, one or more sensing entities may reject the request with (e.g., appropriate) cause codes (e.g., unavailable, sensing service not supported due to low power). For example, a RAN node (e.g., 702) may reject the request when it is not able to commit resource(s) to this task. Information received in procedures 730 to 736 may be used for allowing the sensing entities to accept or reject the specific task (e.g., in the sensing response) and/or reserve and/or allocate resources to this specific task. In examples where resources are reserved, it may specify the time it may be reserved for. The sensing NF 710 may use the information gathered herein, for example at procedure 738, to select the (e.g., suitable) sensing entities (e.g., as opposed to potentially suitable sensing entities). The WTRU sensing capability, sensing mode, sensing authorization, and/or user consent may be checked from the UDM 714, for example, when a sensing WTRU is selected.

[0138] At 730 the sensing NF 710 may send one or more sensing request to one or more RAN nodes (e.g., 702) selected for the sensing task. This message may include one or more sensing requirements, as described herein, chosen for this sensing entity. This message may include the sensing mode chosen for this sensing entity.

[0139] At 732, the sensing NF 710 may receive a response from the RAN node (e.g., 702). This message may indicate whether the sensing request is accepted or rejected. This message may include one or more sensing capabilities, as described herein, that may be offered to this sensing task.

[0140] At 734, the sensing NF 710 may send one or more sensing requests to one or more WTRUs (e.g., 702) selected for the sensing task. This message may include one or more sensing requirements, as described herein, chosen for this sensing entity. This message may include the sensing mode chosen for this sensing entity. For example, the WTRU may receive a sensing response for the sensing task. The sensing response may indicate one or more candidate sensing entities and/or one or more capabilities associated with each candidate sensing entity.

[0141] At 736, the sensing NF 710 may receive a response from the WTRU (e.g., 702). This message may indicate whether the sensing request is accepted or rejected. This message may include one or more sensing capabilities, as described herein, that may be offered to this sensing task.

[0142] At 738, based on the one or more responses received for the sensing requests to the one or more WTRUs (e.g., 702) and/or one or more RAN nodes (e.g., 702), for example, the sensing NF 710 may select the one or more sensing entities for the sensing task.

[0143] At 740, the sensing NF 710 may send a response message to the WTRU 702 and/or RAN node 702, with the information of the sensing service and/or the sensing entity(ies) selected for the sensing task. This message may include information, as described herein, of the one or more sensing entities selected for the sensing task, and/or their respective capability(ies). For example, the WTRU 702 may receive an indication of at least a subset of the one or more candidate sensing entities.

[0144] At 742, if a list of potential sensing entities received by the sensing NF 710 includes one or more (e.g., multiple) candidates that are to be (e.g., needs to be) chosen, for example, the WTRU 702 and/or RAN node 702 may select the one or more sensing entities for the sensing task. For example, the WTRU 702 may select one or more sensing entities from the one or more candidate sensing entities based on the capabilities associated with each candidate sensing entity. The WTRU 702 being configured to select the one or more sensing entities may include the WTRU 702 being configured to confirm the at least subset of the candidate sensing entities (e.g., received at 740).

[0145] An AF may perform the sensing entity selection, and/or may report to the sensing NF 710. In examples, procedures 738 and/or 742 may be executed. In examples, both procedures 738 and 742 may be executed.

[0146] At 744, if procedure 742 was executed, for example, the WTRU 702 and/or RAN node 702 may update the sensing NF 710 of the selection(s) made (e.g., during procedure 742). This may include the selected sensing entities and/or their respective sensing modes. This may be sent as a configuration update request, and/or the 5GS may send a configuration update in response, updating the configuration on the sensing entity. The configuration update may be sent to one or more (e.g., all) sensing entities. For example, the WTRU 702 may send a configuration message. The configuration message may indicate the selected one or more sensing entities.

[0147] One or more of the following procedures may be used for configuring and/or initializing and/or starting the sensing task, for example, once entities are discovered.

[0148] At 746, the one or more sensing entities may be configured for the sensing task and/or the task may get initiated by the sensing NF 710. If procedure 742 is to be executed, for example, the sensing NF 710 may wait for the message send during procedure 744. The sensing NF 710 may send one or more configuration and/or initiation messages to the chosen

sensing entities. The configuration may include one or more (e.g., any) of the parameters, as described herein, to be used for this (e.g., sensing) task. The sensing entities may receive an indication on when to start the sensing task. For example, the indication on to start the sensing task may be specified as a timer value. The sensing NF 710 may specify if further configuration may be included (e.g., required). For example, the sensing entities may (e.g., be required to) communicate with each other (e.g., one or more other sensing entities) to calibrate its parameter(s). For example, the WTRU 702 may receive sensing task configuration information. The sensing task configuration information may include information for the WTRU 702 to perform the sensing task. The sensing task information may include a timer value. The WTRU 702 may start performing the sensing task based on the timer value. The WTRU 702 may be a first sensing entity. The selected one or more sensing entities may include the first sensing entity and a second entity. The WTRU 702 may be configured to communicate with the second sensing entity, for example, in accordance with the received sensing task configuration information.

[0149] At 748, the configured sensing entities may communicate with each other for updating their configuration. These may be RRC configurations. For example, the WTRU 702 being configured to communicate with the second sensing entity may include the WTRU 702 being configured to receive updated information, from the sensing entity, to update and/or calibrate at least the one or more requirement parameters. The WTRU 702 may update and/or calibrate the at least one or more requirement parameters based on, for example, the updated information.

[0150] At 750, the sensing entities may start sensing, for example, based on the sensing task start information received.

[0151] Embodiments are described herein with respect to sensor activation and/or operation management.

[0152] FIGs. 8A and 8B depict a flow chart illustrating an example of sensor activation and/or operation management 800, 850.

[0153] At 814, the RAN and/or WTRU sensing entities (e.g., 802, 804, 806) may register with the 5G system.

[0154] One or more (e.g., all) of the sensing entities involved may receive one or more sensing configurations for the sensing task(s). The sensing entities may be configured to be active, for example, when the sensing entity may start sensing. For example, at 816a, the sensing NF 810 may send sensing configuration to WTRU/RAN node #2 806. The sensing configuration may indicate the WTRU/RAN node #2 806 to be active. For example, at 816b, the sensing NF 810 may send sensing configuration to WTRU/RAN node #1 804. The sensing configuration may

indicate the WTRU/RAN node #1 804 to be active. One or more sensing entities may be configured to be inactive, for example, when the sensing entity may remain until made active. For example, at 816c, the sensing NF 810 may send sensing configuration to WTRU/RAN node #3 802. The sensing configuration may indicate the WTRU/RAN node #3 802 to be inactive active. The configuration may include a sensor activation policy, specifying how the sensor may be turned active. The sensor activation policy may specify if the sensor may be turned on based on a timer value (e.g., timer), network conditions, other environmental change(s), and/or upon receiving an activation message. The configuration may specify one or more policies on sending reports on contextual changes to the network (e.g., sensing NF). The policy may specify one or more parameters to monitor and/or conditions (e.g., thresholds) of each parameter that may (e.g., may need) to be met for sending the report(s). It may specify how these reports may be sent. For example, it may specify report related parameters such as frequency, data, and/or control plane to be used.

[0155] At 818, the sensing task may start. One or more (e.g., all) active sensors may start sensing the target object.

[0156] At 820, one or more changes in sensing context (e.g., location of user, location of target object, location of sensor, distance to target object, interference, resource(s)), may be detected at the sensor entity.

[0157] At 822a, 822b, and/or 822c, the sensing entity(ies) may send a respective sending report. For example, WTRU/RAN node #3 802 may send a report to the sensing NF 810 at 822c. For example, WTRU/RAN node #1 804 may send a report to the sensing NF 810 at 822a. For example, WTRU/RAN node #2 806 may send a report to the sensing NF 810 at 822b. The report may include the respective detected contextual change to the sensing NF 810. This message may specify the type and/or the degree of change (e.g., distance to target object change ~ 2m). This may be similar to (e.g., existing) ProSe Remote WTRU report, another (e.g., new) sensing report that may include (e.g., allow) one or more sensing entities to send one or more (e.g., various) reports such as context updates and/or active/deactivated updates to the 5GS.

[0158] At 824, the sensing NF 810 may obtain information of one or more potential (e.g., candidate) sensing entities. This information may include information of WTRUs and/or information of RAN nodes (e.g., 802, 804, 806). The sensing NF 810 may communicate with the AMF 808 for obtaining information of the WTRUs and/or RAN nodes (e.g., 802, 804, 806).

[0159] At 826, the sensing NF 810 may determine if the currently known sensing entity(ies) are satisfactory for (e.g., ensuring) that the one or more sensing requirements of the sensing task

are met. If the sensing NF 810 determines that one or more other (e.g., new) sensing entities could be incorporated into the task, it may trigger discover procedures (e.g., as described herein).

[0160] At 828, the sensing NF 810 may choose and/or may update the sensing entities used for the sensing task. For example, the sensing NF 810 may incorporate one or more other (e.g., newly discovered) sensing entities. The sensing NF 810 may (e.g., then) determine an activation and/or deactivation strategy for one or more (e.g., all) of the sensing entities. For example, while the target object is mobile, the sensing NF 810 may determine to activate one or more sensing entities in coverage and/or may deactivate one or more sensing entities that are out of coverage. In examples, based on the one or more other (e.g., newly) discovered sensing entities, one or more (e.g., existing) sensing modes of the previously selected/used sensing modes may change. In examples, based on the one or more other (e.g., newly) discovered sensing entities, one or more (e.g., existing) sensing nodes of the previously selected and/or used sensing nodes may change.

[0161] At 830, based on the decision made herein (e.g., at procedure 828), the sensing NF 810 may send a sensor deactivation message to the one or more sensing entities that are decided to be deactivated. This message may include one or more conditions for deactivation. For example, the message may specify one or more deactivation start conditions and/or one or more deactivation stop conditions, which may (e.g., need to) be satisfied when the sensor changes its status. For example, once one or more conditions are met, one or more sensing entities may go into a deactivation state, as the sensor may be deactivated for only a period of time. Additionally or alternatively, it may go to a non-active ready state where it may wait for another (e.g., new) activation request to be activated. For example, the deactivation start condition may be a timer value, which upon expiring the sensor may be deactivated for a specific duration. In examples, where the same entity host one or more (e.g., multiple) sensors, this message may specify which sensor is to be deactivated.

[0162] At 832, the sensing entity which received the sensor deactivation message, may deactivate the sensor, for example, based on the one or more conditions (e.g., as described herein). The sensing entity may report back to the sensing NF 810 that it has deactivated the sensor (e.g., with related parameters such as timer information).

[0163] At 834, the sensing NF 810 may send a sensor activation message, for example based on the determination made during procedure 828, to the one or more sensing entities that are decided to be activated. This message may include one or more conditions for activation. For example, it may specify one or more activation start conditions and/or one or more activation

stop conditions, which may be included (e.g., needed) to satisfy when the sensor is changing its status. For example, the activation start condition may be a timer value, which upon expiring the sensor may be activated for a specific duration. In examples, where the same entity hosts one or more (e.g., multiple) sensors, this message may specify which sensor is to be activated.

[0164] At 836, the sensing entity which received the sensor activation message may activate the sensor, for example, based on the one or more conditions (e.g., as described herein). The sensing entity may report back to the sensing NF 810 that it has activated the sensor (e.g., with related parameters such as timer information).

[0165] At 838, the one or more sensing entities that are determined to have no changes to its status may receive a message indicating that it may continue to sense with the existing configuration. This message may if there are one or more changes to existing configuration, and if yes, it may include the one or more configuration changes.

[0166] When referred to activation and deactivation of sensors, it may be concerned of the activation and/or deactivation of the sensor itself. For example, the small form factor and/or resource scales may be switched off, and/or put into an idle mode, for example, upon receiving a deactivation message, and turned back on upon receiving an activation (e.g., activation message). There may be one or more other examples where sensor behavior may differ. In examples, the activation and/or deactivation messages may (e.g., only) act on processes that are related to the specific sensing task. For example, it may (e.g., only) activate and/or deactivate the sending of the one or more measurement reports that belong to that specific task, while the sensor itself may remained turned on, and in examples may continue to sense the environment. This may be applicable to one or more examples where a single sensor is shared among one or more (e.g., multiple) sensing tasks, for example, if a base station is acting as an RF sensor, a deactivation message may (e.g., only) affect the corresponding sensing task. In examples, the activation and/or deactivation message may be sent (e.g., either) to the sensor itself and/or to a logical entity where the sensing output is handed. In examples, activation and/or deactivation of a sensor may entail filtering in and/or our received sensing data from the sensor, and/or sensing and/or stopping sensing reports to the corresponding entity / sensing data consumer.

[0167] The procedures and/or embodiments described herein may illustrate examples where a RAN node may be used as a sensing entity. The procedures and/or embodiments described herein may (e.g., also) be used, for example, if non-3GPP access networks are used. For example, non-3GPP access nodes may communicate with 5G system through N3IWF (e.g., for

registering its capability(ies)), to communicate with the AMF (e.g., 808) and/or sensing NF (e.g., 810).

CLAIMS:

1. A network node comprising:
a processor configured to:
 - receive sensing capability information associated with a plurality of sensing entities, wherein the sensing capability information comprises an indication of a respective sensing mode that is supported by each sensing entity;
 - receive a sensing request, wherein the sensing request comprises an indication of a sensing service requirement;
 - select a plurality of candidate sensing entities from the plurality of sensing entities based on the sensing service requirement and the sensing capability information associated with each sensing entity of the plurality of sensing entities;
 - receive respective sensing information from each of the plurality of candidate sensing entities, wherein the sensing information indicates a time that each candidate sensing entity of the plurality of candidate sensing entities is available to perform sensing and the respective sensing mode that is supported by each of the plurality of candidate sensing entities;
 - select a subset of candidate sensing entities from the plurality of candidate sensing entities based on the respective sensing information from each of the plurality of candidate sensing entities; and
 - send a sensing response, wherein the sensing response indicates the subset of candidate sensing entities.
2. The network node of claim 1, wherein the sensing mode is monostatic or bi-static.
3. The network node of claim 1, wherein the sensing response indicates the available time of each of the subset of sensing entities to perform the sensing.
4. The network node of claim 1, wherein the sensing request comprises a required sensing mode, and wherein the processor is configured to select the plurality of candidate sensing entities based on the required sensing mode.

5. The network node of claim 1, wherein the sensing capability information comprises one or more of: a data reporting frequency, a sampling size, one or more supported sensing services, a sensor output data type, a type of sensing data processing, one or more data compression capabilities, protocol information for sensing data and control data, a sensing area, a sensing node role, authorization information, an entity availability, an entity utilization, or a network transmission information for sensing data and control data.
6. The network node of claim 1, wherein the sensing service requirement comprise one or more of data time validity, one or more delay requirements, a proximity, a location of interest, one or more sensing data communication preferences, a data reporting frequency, a sampling size, a time frame, a sensing service, one or more quality of service (QoS) parameters, or a sensing speed.
7. The network node of claim 1, wherein the sensing capability information is received from an access and mobility management function (AMF), wherein the sensing capability information comprises one or more of sensing waveforms, a covered area, a maximum distance to a sensing target, or a maximum power used for sensing.
8. The network node of claim 1, wherein the processor is further configured to send configuration information to each sensing entity of the subset of candidate sensing entities, wherein the configuration information comprises sensing task information for each sensing entity of the subset of candidate sensing entities to perform a sensing task.
9. The network node of claim 8, wherein the sensing task information comprises a respective timer value, for each sensing entity of the subset of candidate sensing entities, to start performing the sensing task based on the respective timer value.
10. The network node of claim 8, wherein the subset of candidate sensing entities comprises a first sensing entity and a second sensing entity, and wherein the sensing task information comprises an indication that the first sensing entity is to communicate with the second sensing entity.

11. A method performed by a network node, the method comprising:
- receiving sensing capability information associated with a plurality of sensing entities, wherein the sensing capability information comprises an indication of a respective sensing mode that is supported by each sensing entity;
 - receiving a sensing request, wherein the sensing request comprises an indication of a sensing service requirement;
 - selecting a plurality of candidate sensing entities from the plurality of sensing entities based on the sensing service requirement and the sensing capability information associated with each sensing entity of the plurality of sensing entities;
 - receiving respective sensing information from each of the plurality of candidate sensing entities, wherein the sensing information indicates a time that each candidate sensing entity of the plurality of candidate sensing entities is available to perform sensing and the respective sensing mode that is supported by each of the plurality of candidate sensing entities;
 - selecting a subset of candidate sensing entities from the plurality of candidate sensing entities based on the respective sensing information from each of the plurality of candidate sensing entities; and
 - sending a sensing response, wherein the sensing response indicates the subset of candidate sensing entities.
12. The method of claim 11, wherein the sensing mode is monostatic or bi-static.
13. The method of claim 11, wherein the sensing response indicates the available time of each of the subset of sensing entities to perform the sensing.
14. The method of claim 11, wherein the sensing request comprises a required sensing mode, and wherein the processor is configured to select the plurality of candidate sensing entities based on the required sensing mode.
15. The method of claim 11, wherein the sensing capability information comprises one or more of: a data reporting frequency, a sampling size, one or more supported sensing services, a sensor output data type, a type of sensing data processing, one or more data compression capabilities, protocol information for sensing data and control data, a sensing area, a sensing node role, authorization information, an entity availability, an entity utilization, or a network transmission information for sensing data and control data.

16. The method of claim 1, wherein the sensing service requirement comprise one or more of data time validity, one or more delay requirements, a proximity, a location of interest, one or more sensing data communication preferences, a data reporting frequency, a sampling size, a time frame, a sensing service, one or more quality of service (QoS) parameters, or a sensing speed.

17. The method of claim 11, wherein the sensing capability information is received from an access and mobility management function (AMF), wherein the sensing capability information comprises one or more of sensing waveforms, a covered area, a maximum distance to a sensing target, or a maximum power used for sensing.

18. The method of claim 11, further comprising sending configuration information to each sensing entity of the subset of candidate sensing entities, wherein the configuration information comprises sensing task information for each sensing entity of the subset of candidate sensing entities to perform a sensing task.

19. The method of claim 18, wherein the sensing task information comprises a respective timer value, for each sensing entity of the subset of candidate sensing entities, to start performing the sensing task based on the respective timer value.

20. The method of claim 18, wherein the subset of candidate sensing entities comprises a first sensing entity and a second sensing entity, and wherein the sensing task information comprises an indication that the first sensing entity is to communicate with the second sensing entity.

100

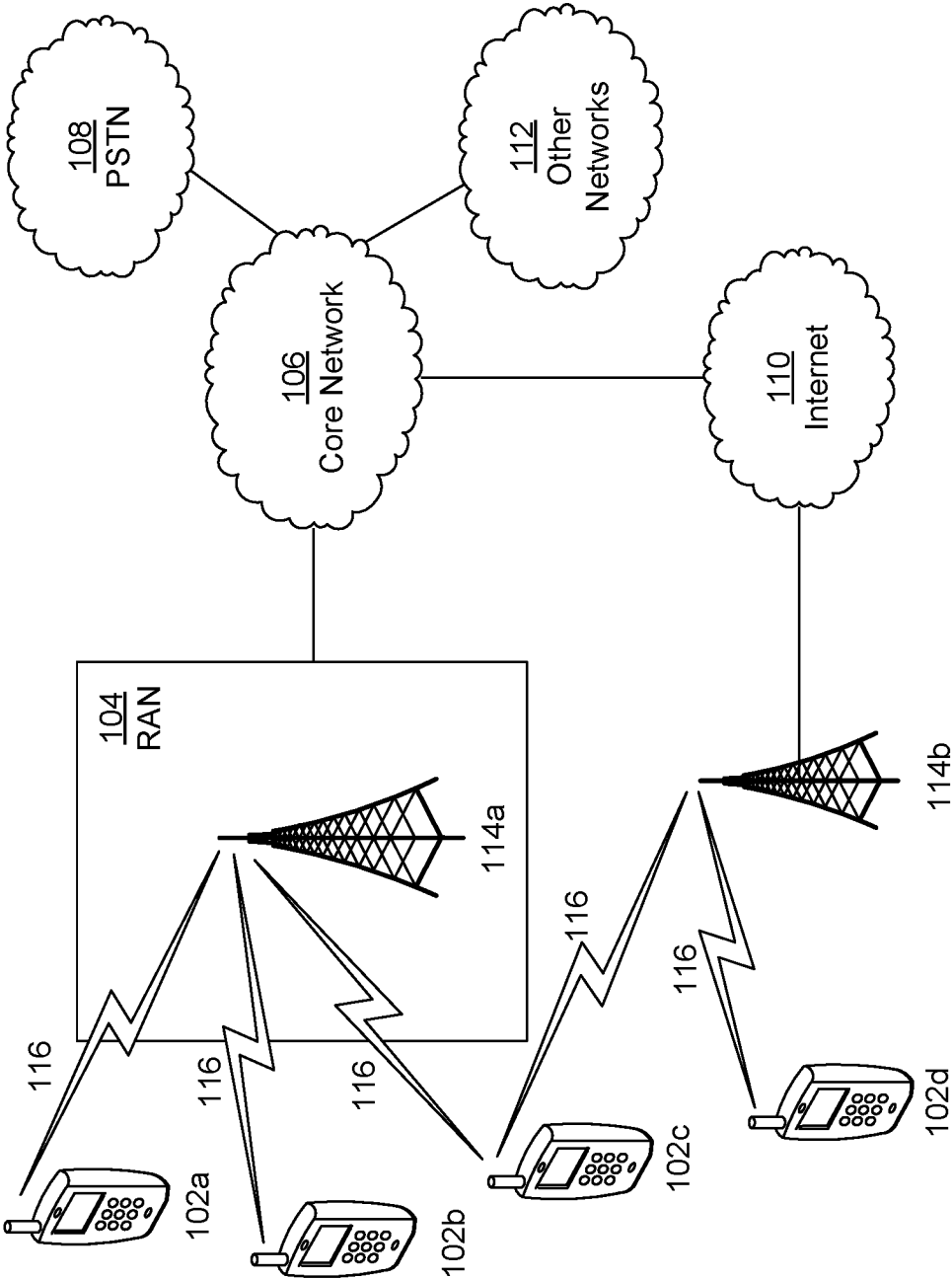
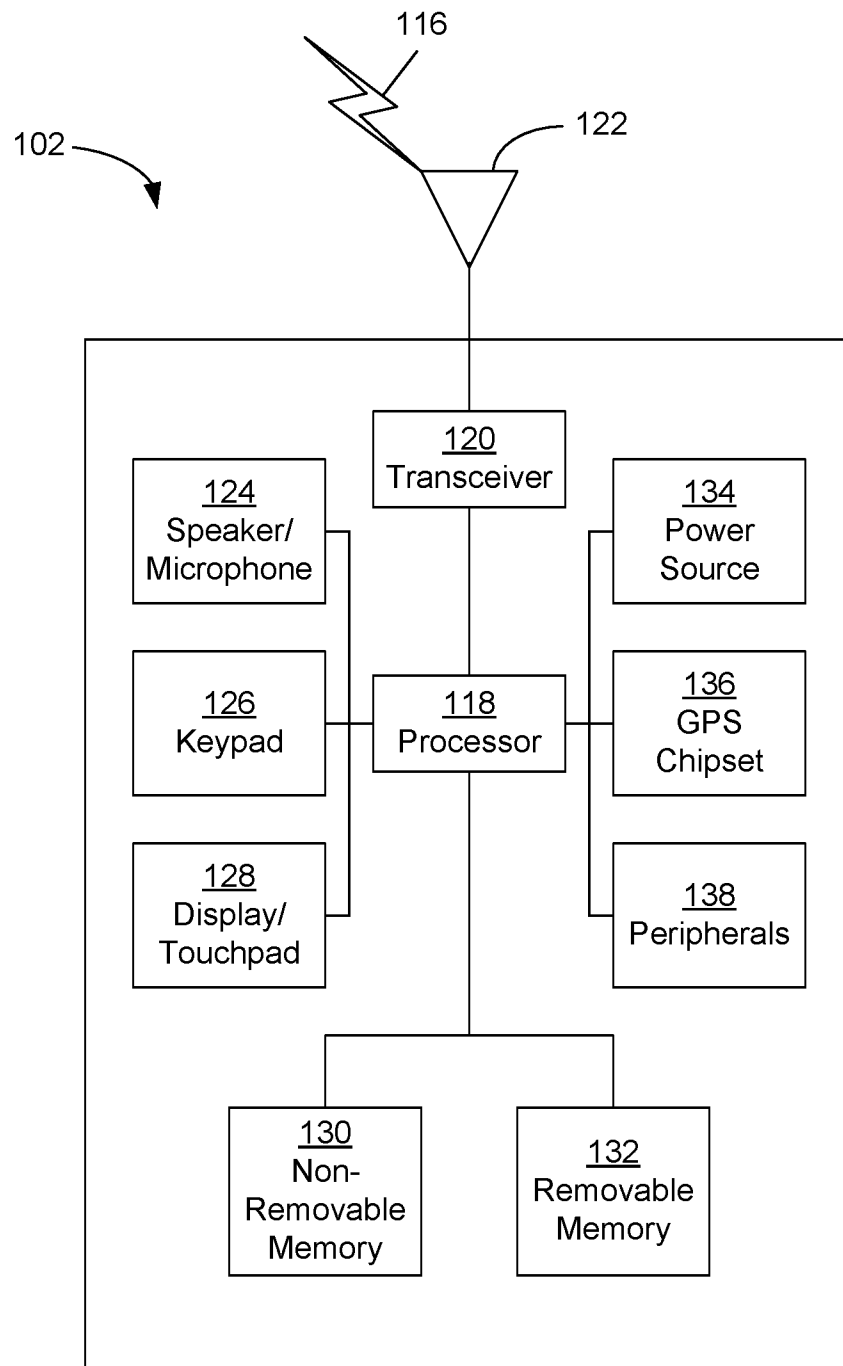


FIG. 1A

2/15

**FIG. 1B**

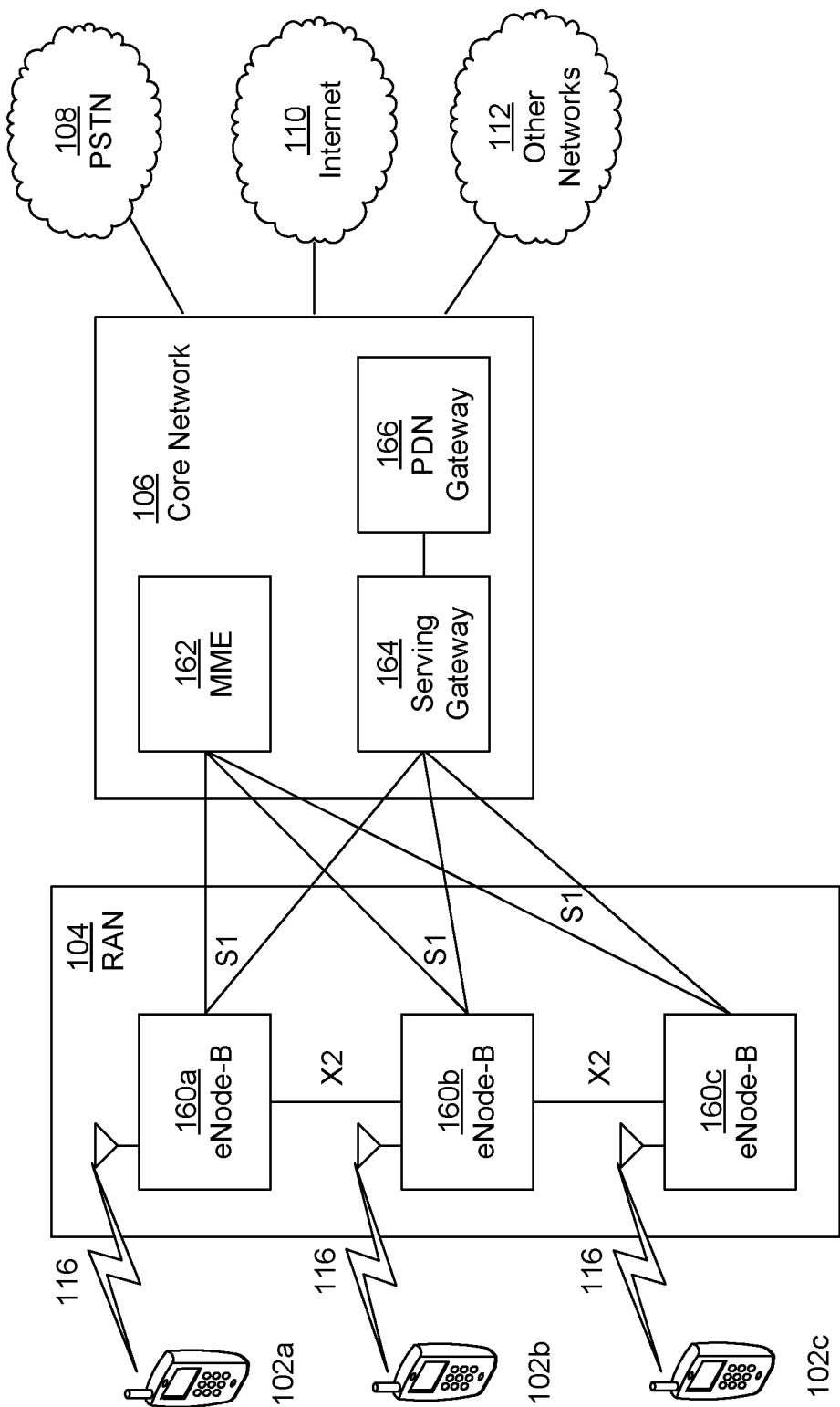


FIG. 1C

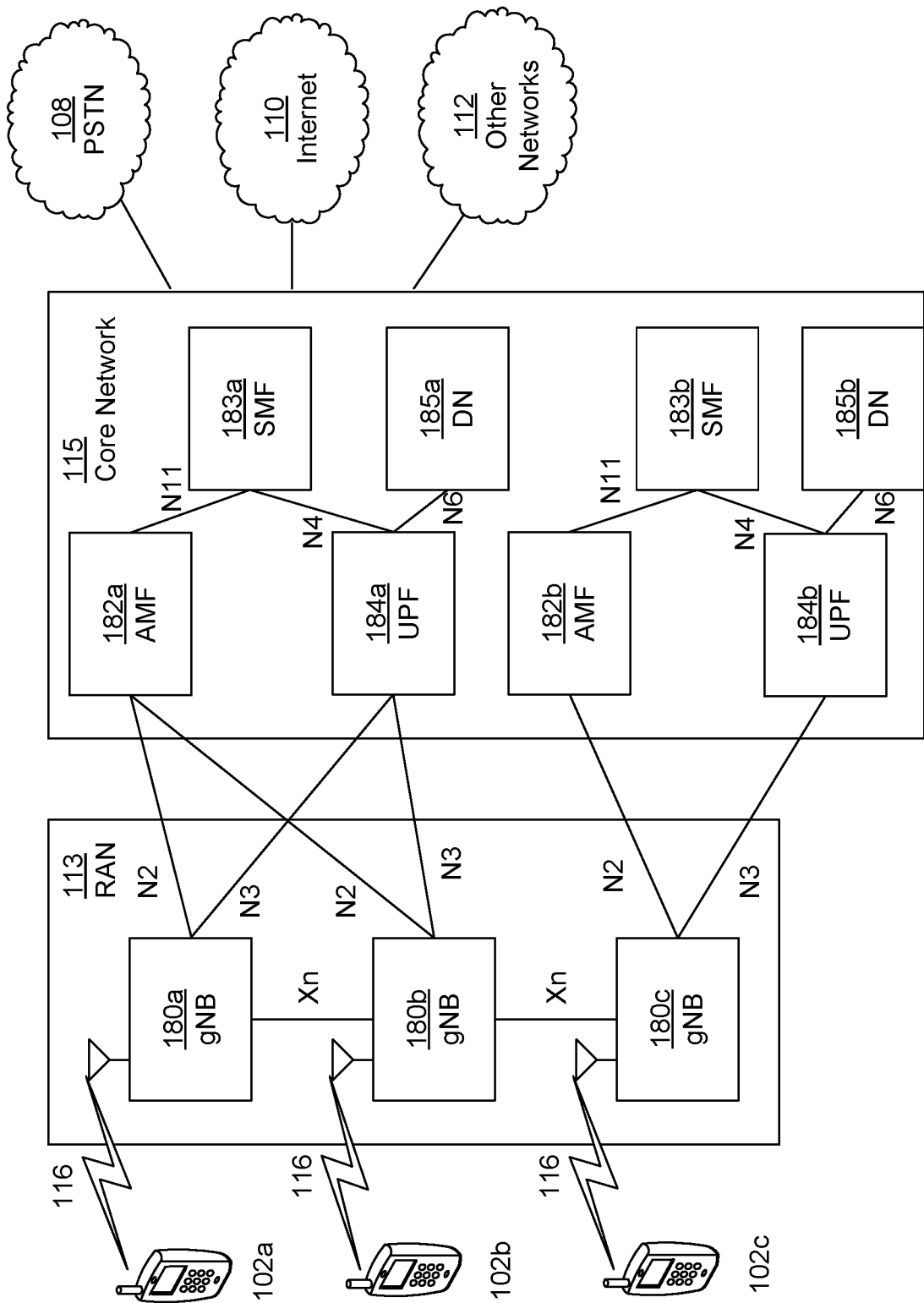


FIG. 1D

200

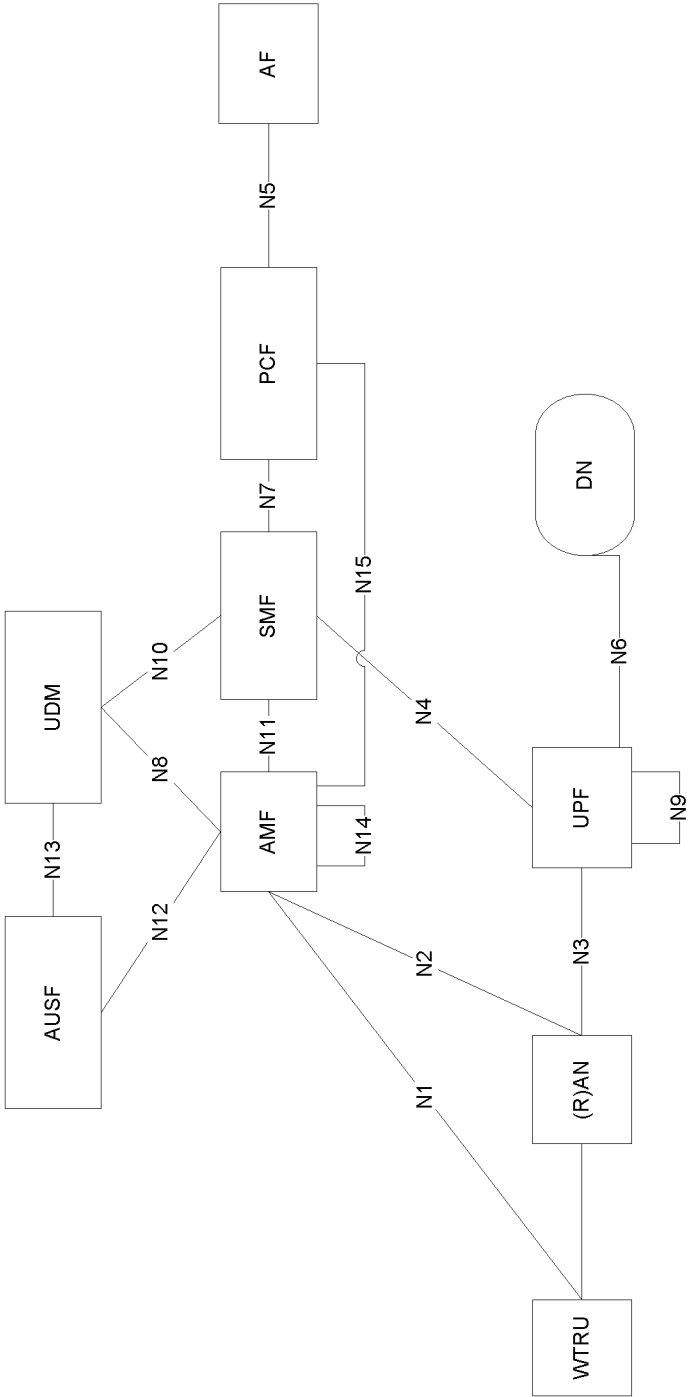


FIG. 2

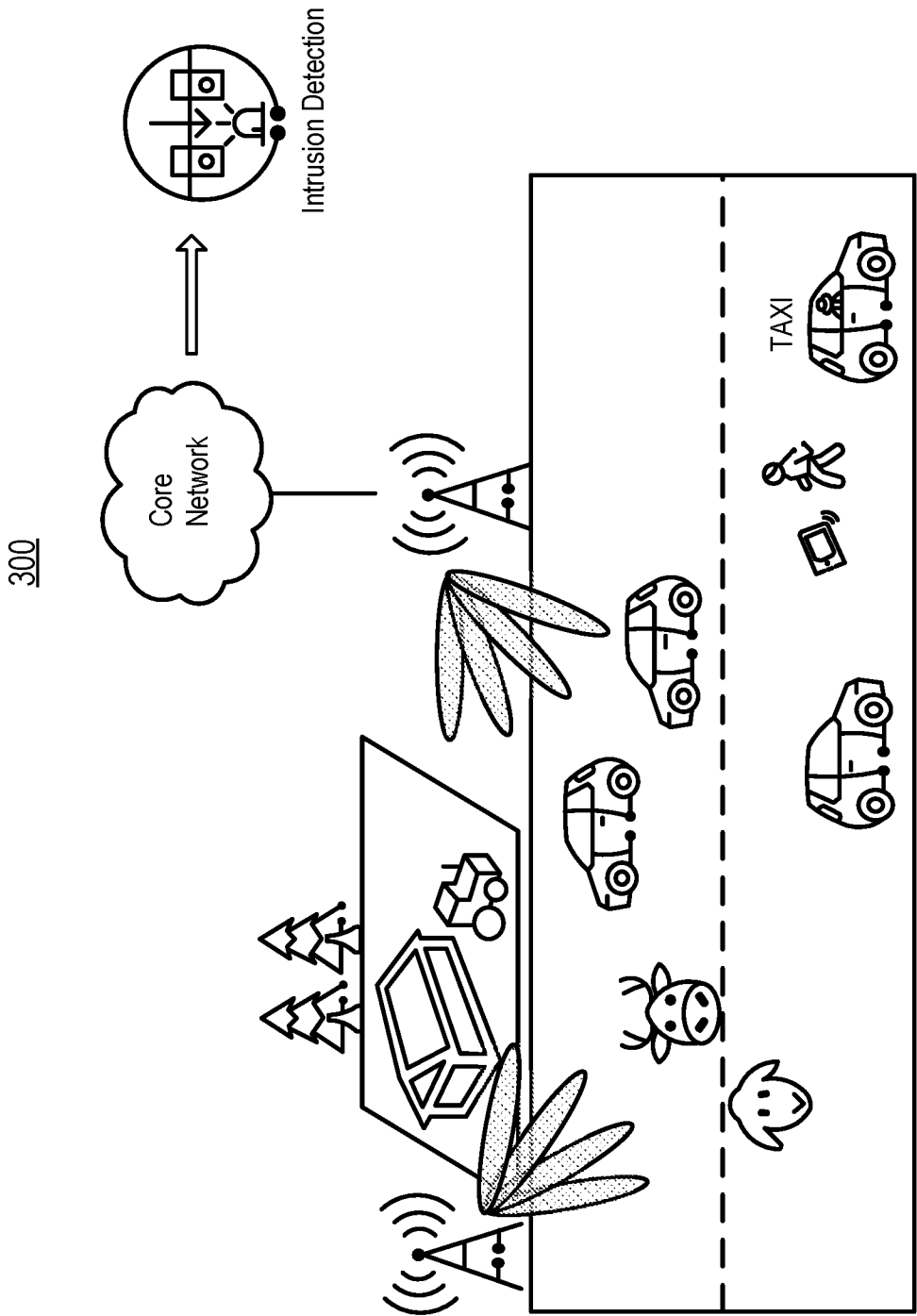


FIG. 3

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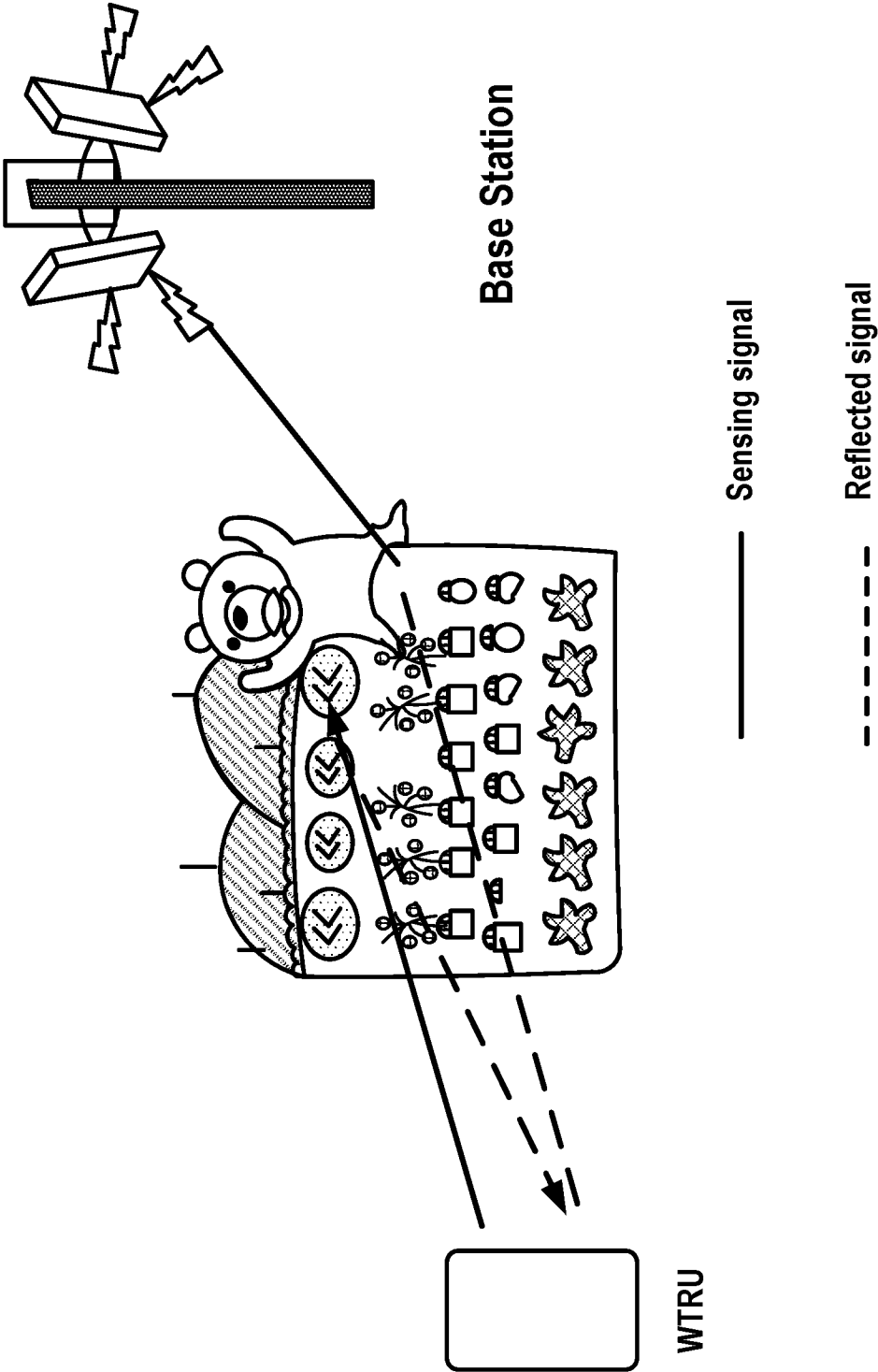


FIG. 4

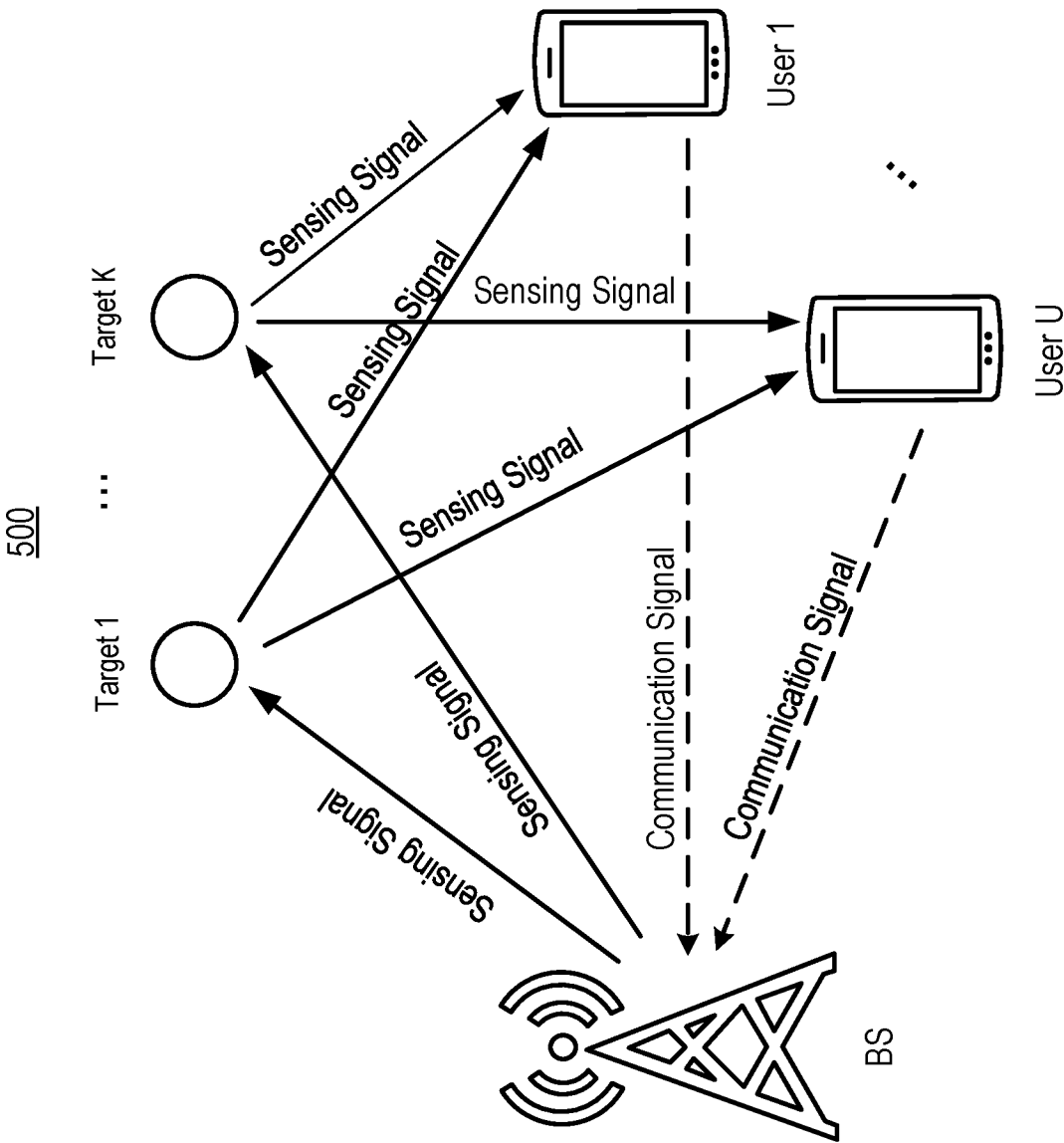
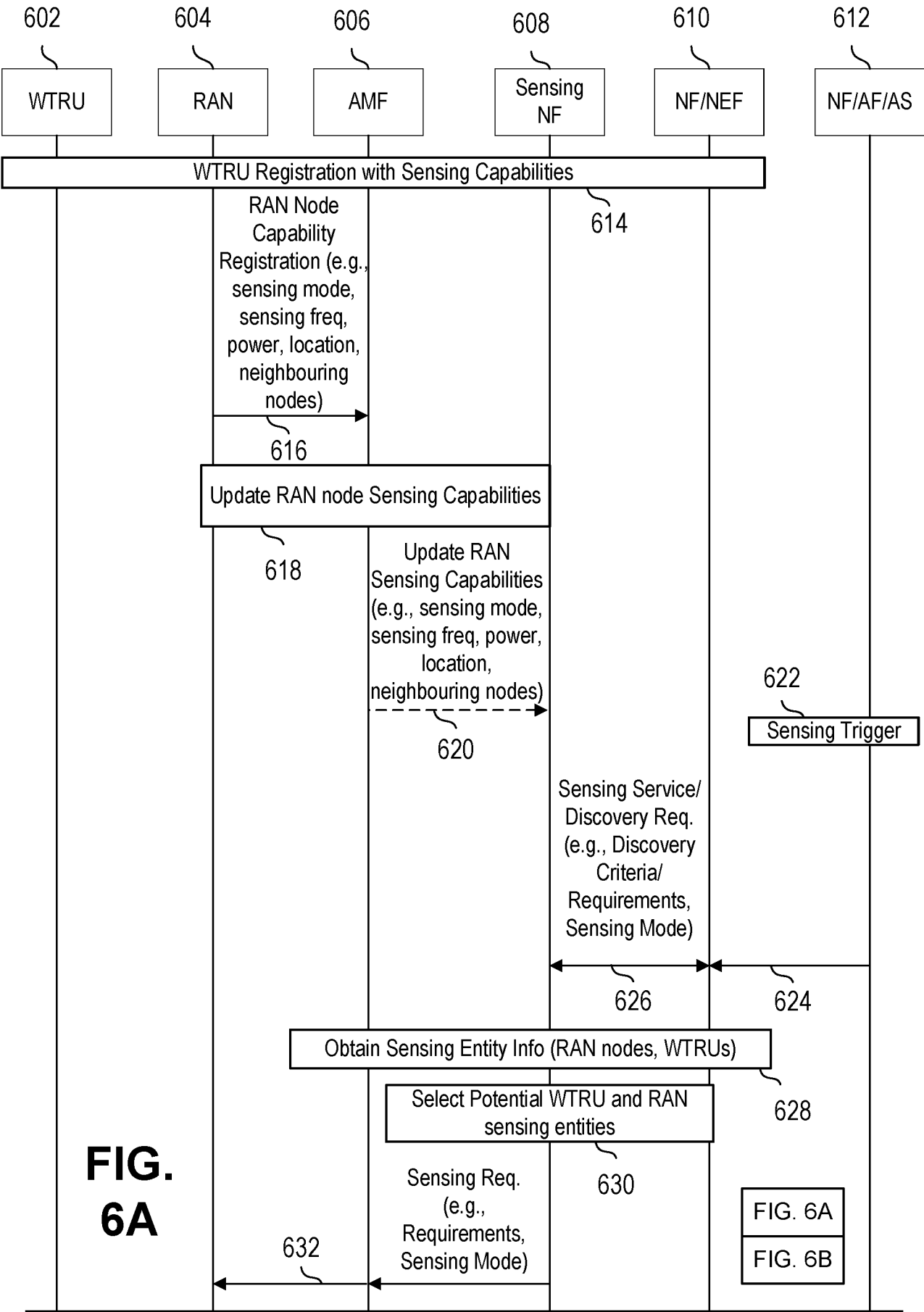


FIG. 5

600



675

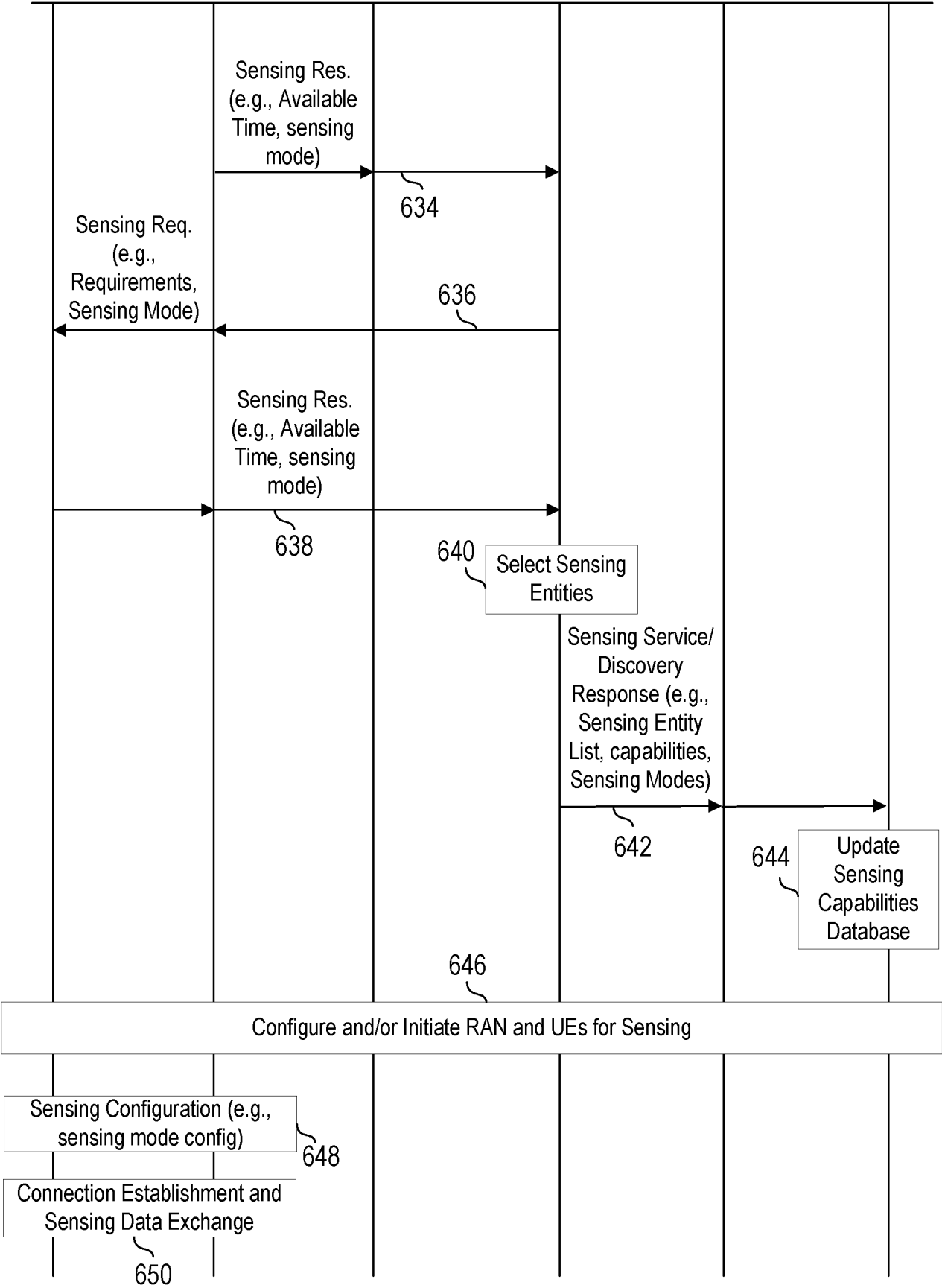
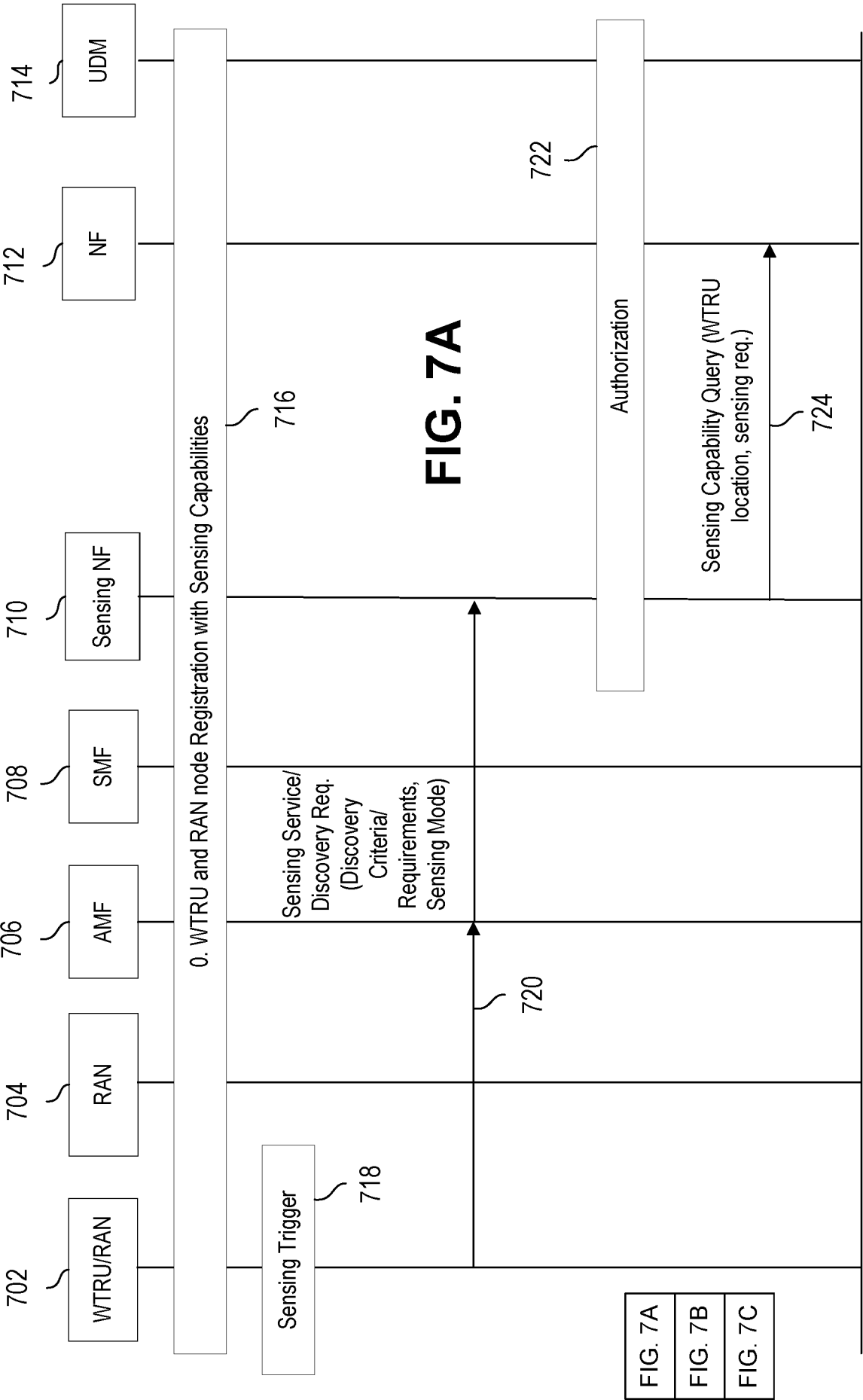
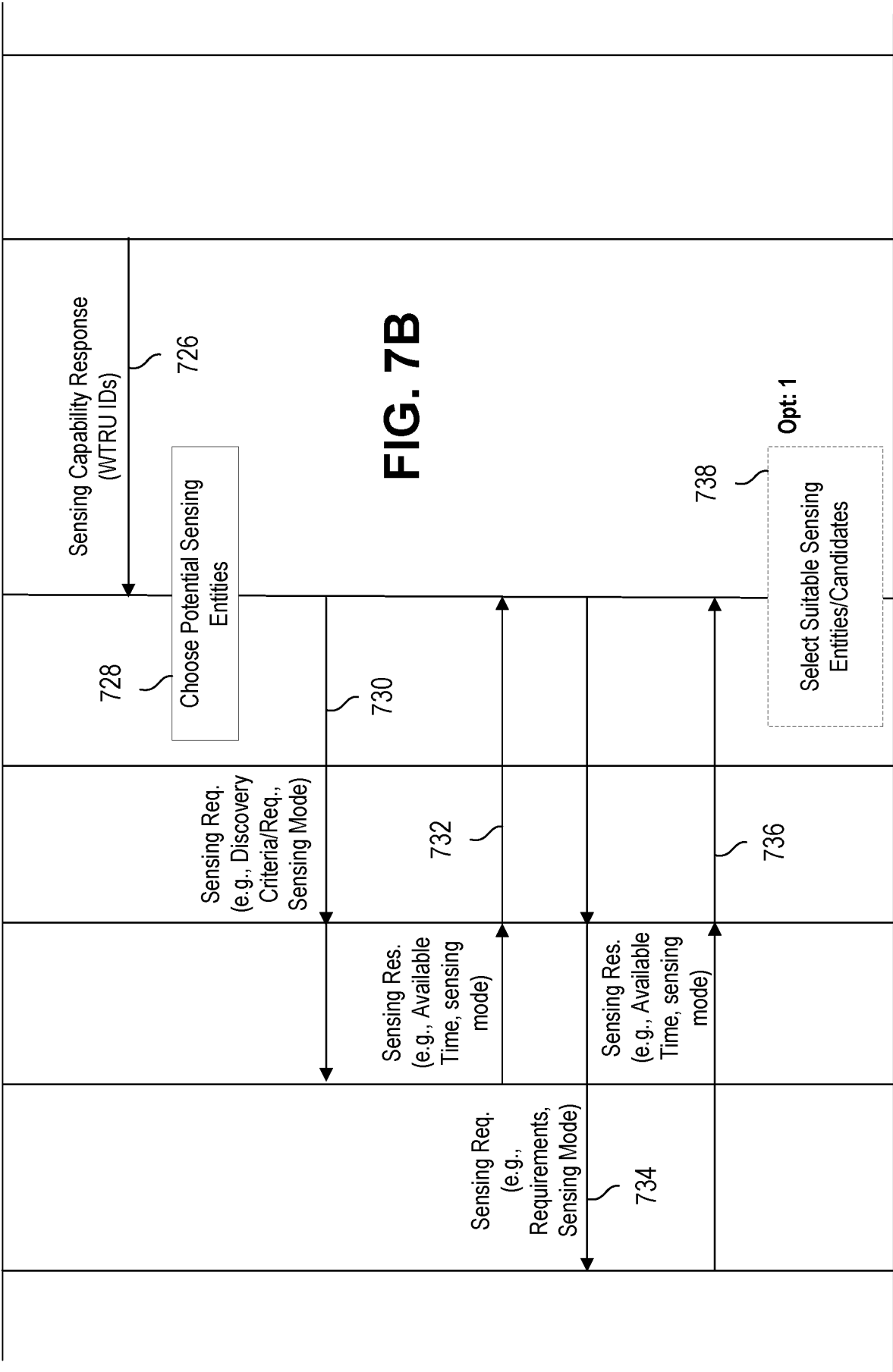


FIG. 6B

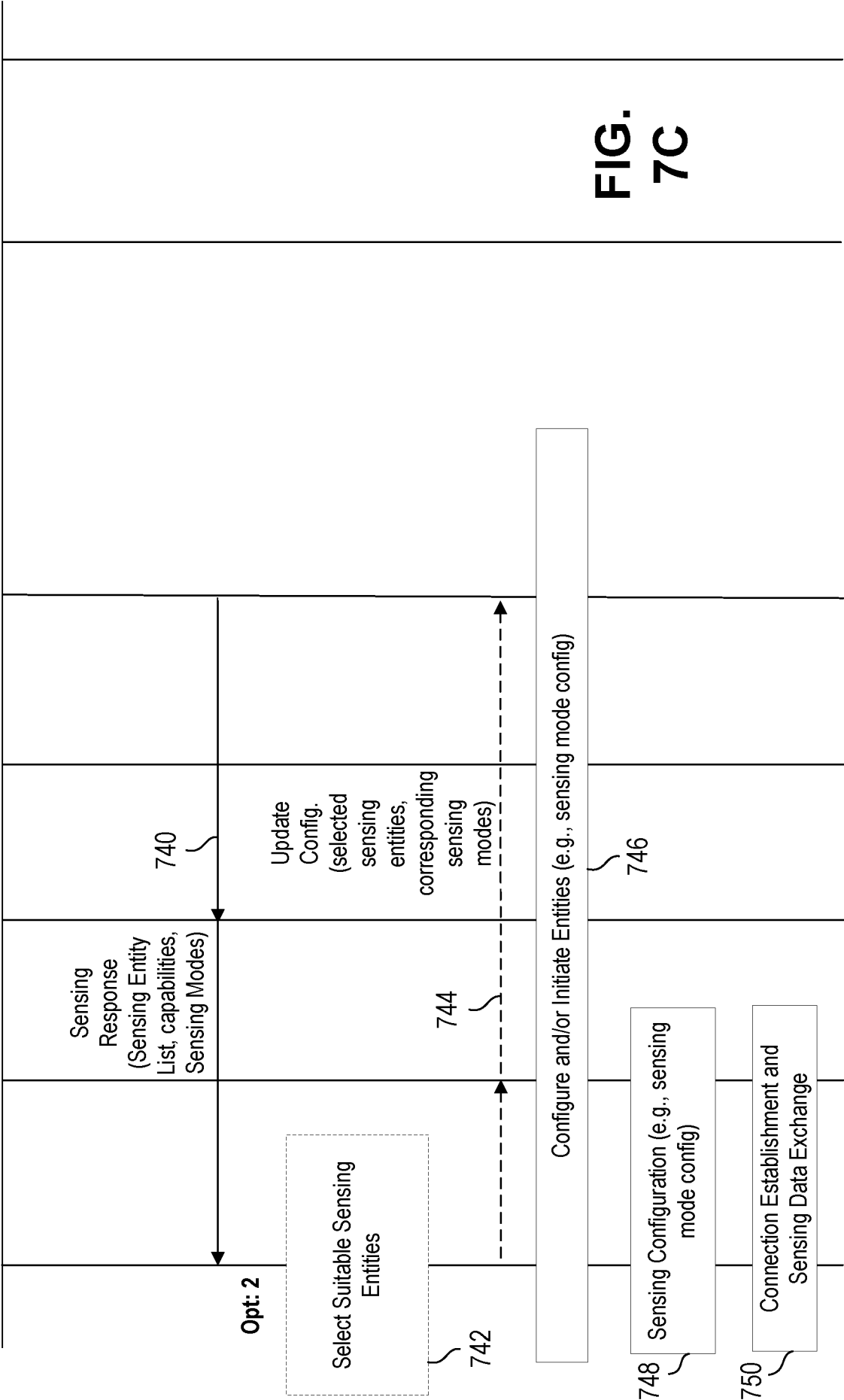
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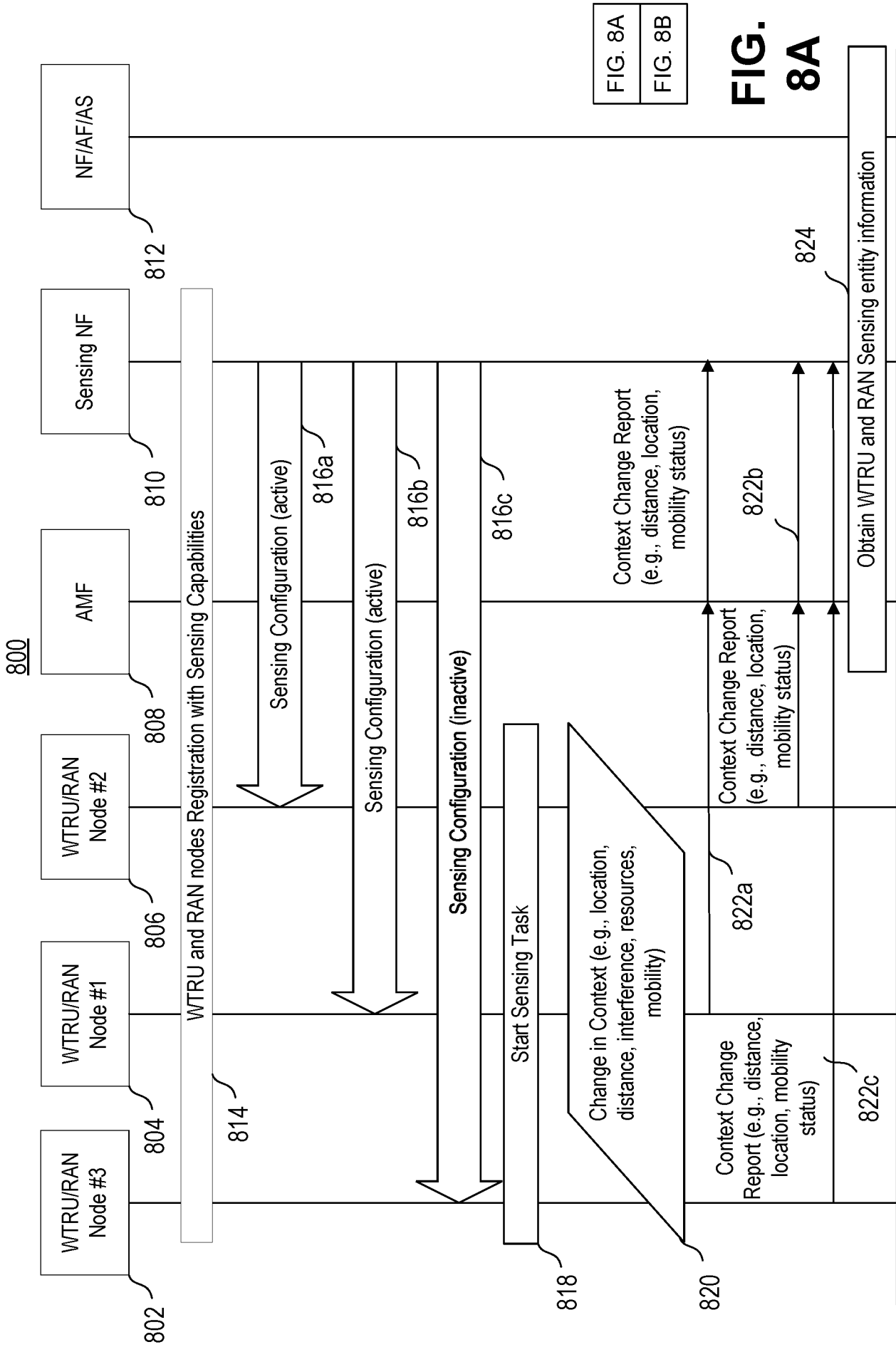


725



775





850

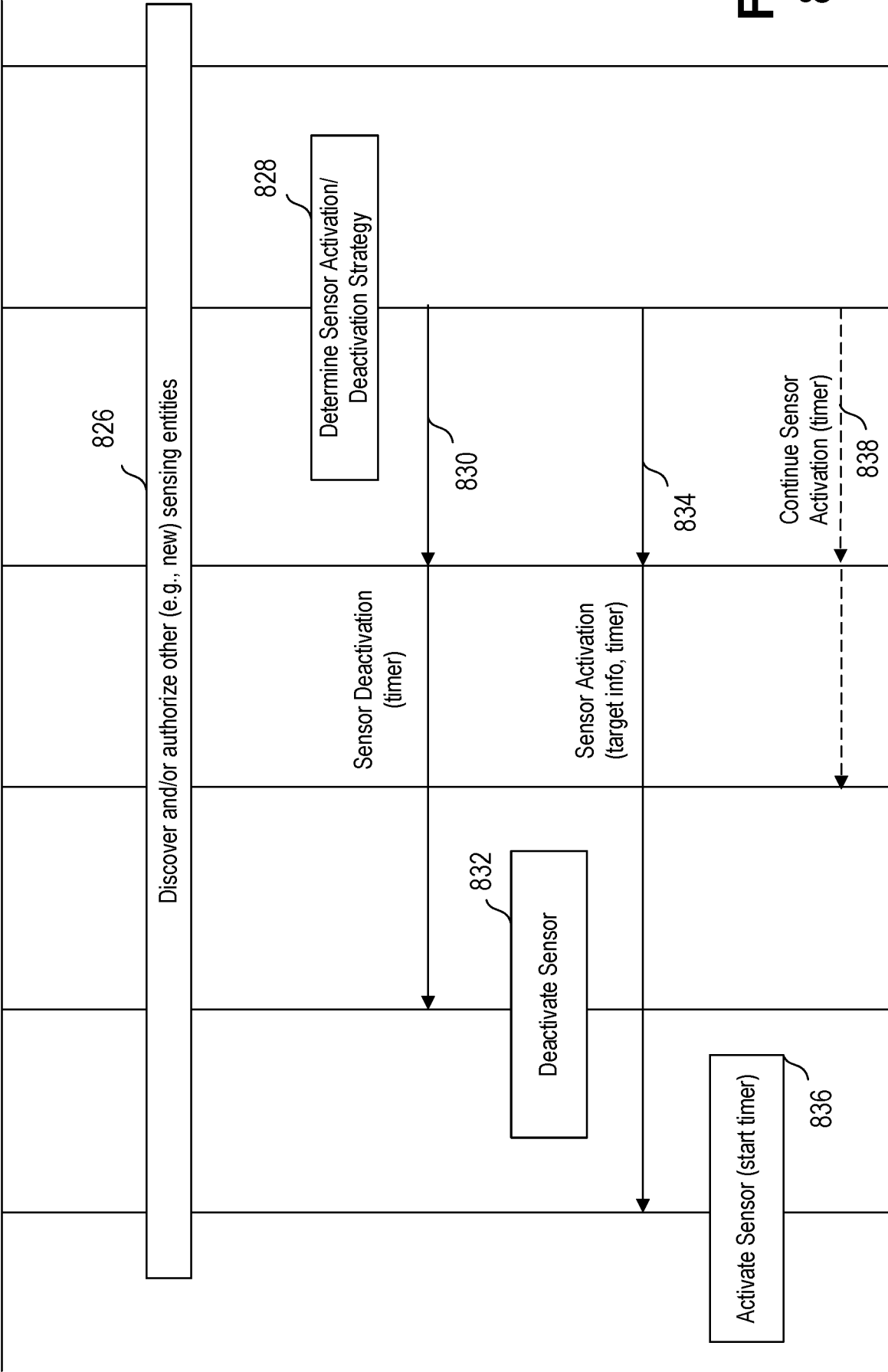


FIG.
8B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2025/010277

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W4/02 G01S13/76 H04W4/38 H04W8/00 H04W8/24
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W G01S

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2023/225863 A1 (BEIJING XIAOMI MOBILE SOFTWARE CO LTD [CN]) 30 November 2023 (2023-11-30) description corresponding to the steps S202-S206	1-20
Y	WO 2023/231865 A1 (VIVO MOBILE COMMUNICATION CO LTD [CN]) 7 December 2023 (2023-12-07) abstract & US 2025/097752 A1 (YUAN YANNAN [CN] ET AL) 20 March 2025 (2025-03-20) paragraphs [0074], [0147] - [0173]	1-20
A	WO 2023/184119 A1 (BEIJING XIAOMI MOBILE SOFTWARE CO LTD [CN]) 5 October 2023 (2023-10-05) abstract - / - -	1, 2, 11, 12



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

27 March 2025

Date of mailing of the international search report

04/04/2025

Name and mailing address of the ISA/

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Authorized officer

Blanco Cardona, P

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2025/010277

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	& EP 4 503 779 A1 (BEIJING XIAOMI MOBILE SOFTWARE CO LTD [CN]) 5 February 2025 (2025-02-05) paragraphs [0038], [0060], [0061] -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2025/010277

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