

(51) International Patent Classification:
H04W 56/00 (2009.01)(21) International Application Number:
PCT/US2019/053238(22) International Filing Date:
26 September 2019 (26.09.2019)

(25) Filing Language: English

(26) Publication Language: English

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

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

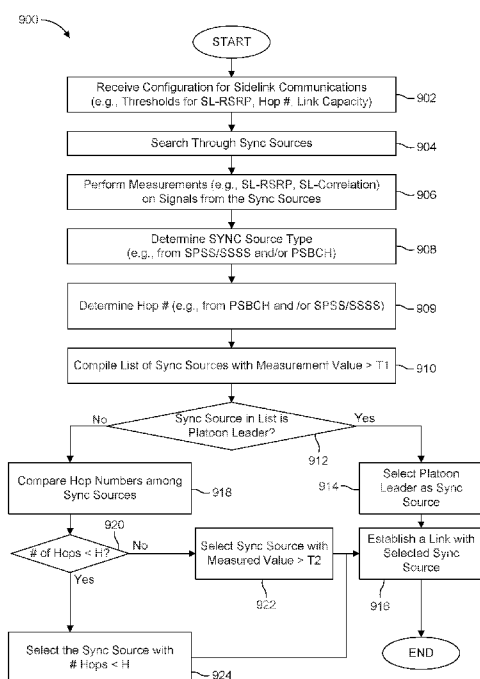
(54) Title: **SIDELINK SYNCHRONIZATION METHODS FOR V2X IN NR**

FIG. 9

(57) Abstract: Methods for sidelink synchronization may be used by a wireless transmit/receive unit (WTRU) that wants to join a group of WTRUs, such as a vehicle platoon. The WTRU may receive configuration information for sidelink communications including measurement thresholds. The WTRU may monitor a sidelink channel for signals from synchronization sources. The WTRU may perform sidelink measurements and determine synchronization source type and hop number for the synchronization sources. The WTRU may compile a list of synchronization sources with sidelink measurement above a first threshold and select a platoon leader type. If there is no platoon leader in the list, the WTRU may select the synchronization source with hop number below a hop threshold. Otherwise, the WTRU may select the synchronization source for which the value of the sidelink measurement is greater than a second sidelink measurement threshold. The WTRU may establish a link with the selected synchronization source.

Published:

— *with international search report (Art. 21(3))*

SIDELINK SYNCHRONIZATION METHODS FOR V2X IN NR**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Application No. 62/736,795, filed September 26, 2018, the contents of which are incorporated herein by reference.

BACKGROUND

[0002] Recent Third Generation Partnership Project (3GPP) standards discussions define several deployment scenarios such as indoor hotspot, dense urban, rural, urban macro, and high speed. Based on general requirements set out by International Telecommunication Union Radiocommunication Sector (ITU-R), Next Generation Mobile Networks (NGMN) and 3GPP, use cases for emerging 5G systems may be broadly classified as enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable and low latency communications (URLLC). These use cases focus on meeting different performance requirements such as higher data rate, higher spectrum efficiency, low power and higher energy efficiency, and/or lower latency and higher reliability. Moreover, a wide range of spectrum bands ranging from 700 MHz to 80 GHz are being considered for a variety of deployment scenarios.

SUMMARY

[0003] Methods for sidelink synchronization may be used by a wireless transmit/receive unit (WTRU) that wants to join a group of WTRUs, such as a vehicle platoon, and may be used for vehicle-to-everything (V2X) in New Radio (NR). The WTRU may receive configuration information for sidelink communications, wherein the configuration information includes measurement thresholds. The WTRU may monitor a sidelink channel for signals from a plurality of synchronization sources. The WTRU may perform sidelink measurements on sidelink synchronization signals from each of the plurality of synchronization sources, and determine synchronization source type and hop number for each of the plurality of synchronization sources based on information carried in the respective sidelink synchronization signal. The WTRU may compile a list of synchronization sources from the plurality of synchronization sources for which a value of the sidelink measurement is greater than a first sidelink measurement threshold. The WTRU may select the synchronization source with synchronization source type that is platoon leader type. If no synchronization source in the list is a platoon leader synchronization source type, then the WTRU may select the synchronization source with hop number less than the first hop number threshold. If no synchronization source in the list of synchronization sources has a hop

number less than a first hop number threshold, then the WTRU may select the synchronization source for which the value of the sidelink measurement is greater than a second sidelink measurement threshold. The WTRU may establish a link with the selected synchronization source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0005] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0006] 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;

[0007] 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;

[0008] 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;

[0009] FIG. 2 is a signaling diagram of an example sidelink WTRU information exchange procedure for communication between a (vehicle) WTRU and the eNB for vehicle-to-everything (V2X) sidelink transmissions;

[0010] FIG. 3 is a network diagram of an example vehicle platoon including a platoon leader and platoon followers;

[0011] FIG. 4 is a flow diagram of an example synchronization source selection method based on measurement, measurement type and synchronization source type;

[0012] FIG. 5 is a flow diagram of an example synchronization source selection method based on absolute and relative measurement, measurement type and synchronization source type;

[0013] FIG. 6 is a flow diagram of an example synchronization source selection method based on measurement, measurement type, synchronization source type and number of hops;

[0014] FIG. 7 is a flow diagram of an example synchronization source selection method based on measurement, measurement type and synchronization source type, number of hops and link capacity;

[0015] FIG. 8 is a flow diagram of an example synchronization source selection method based on measurement, measurement type, synchronization source type, number of hops, link capacity, and traffic load;

[0016] FIG. 9 is a flow diagram of an example synchronization source selection method based on measurement, measurement type and synchronization source type, and number of hops; and

[0017] FIG. 10 is a flow diagram of an example synchronization assistance information method for NR V2X sidelink, which may be performed by a WTRU that is a member of a vehicle platoon.

DETAILED DESCRIPTION

[0018] 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.

[0019] 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 UE.

[0020] 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.

[0021] 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.

[0022] 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).

[0023] 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).

[0024] 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).

[0025] 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).

[0026] 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).

[0027] 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.

[0028] 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.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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).

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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 WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the downlink (e.g., for reception)).

[0042] 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.

[0043] 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.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] 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.

[0051] In representative embodiments, the other network 112 may be a WLAN.

[0052] 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.

[0053] 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.

[0054] 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.

[0055] 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).

[0056] 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).

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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).

[0061] 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).

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] 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.

[0070] 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.

[0071] 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.

[0072] In wireless communications, as the carrier frequency increases, severe path loss may become a crucial limitation to guarantee sufficient coverage. Transmission in millimeter wave (mmW) systems may additionally suffer from non-line-of-sight losses, such as diffraction loss, penetration loss, oxygen absorption loss, and/or foliage loss. During initial access, a base station and WTRU may need to overcome these high path losses and discover each other. Utilizing dozens or even hundreds of antenna elements to generate beamformed signals is an effective way to

compensate for severe path loss by providing significant beamforming gain. Beamforming techniques may include digital, analogue and hybrid beamforming.

[0073] In the 3GPP vehicle-to-everything (V2X) standardization process, several use cases are being considered, including the following use case groups: vehicle platooning, extended sensors, advanced driving and remote driving. Each use case group may have different latency, reliability and data rate requirements such as the examples summarized in Table 1.

Use Case Group	End-to-end latency (ms)	Reliability (%)	Data rate (Mbps)
Vehicle platooning	10	99.99	65
Advanced driving	3	99.999	53
Extended sensors	3	99.999	1000
Remote driving	5	99.999	UL: 25, DL: 1

Table 1: Example latency, reliability and data rate requirements for V2X use case groups

[0074] Use case within each use case group may have different latency, reliability and/or data rate requirements. For example, the lower degree of automation in a video sharing scenario, which may be part of the extended sensors use case group, may have a 50 ms latency requirement, 90% reliability requirement and 10 Mbps data rate requirement. In another example, a higher degree of automation in sensor information sharing between WTRUs supporting V2X application, also part of the extended sensors use case group, may have a 3 ms latency requirements, a 99.999% reliability requirement, and a 25 Mbps data rate requirement.

[0075] In 3GPP V2X, a vehicle may be in transmission mode 3 (i.e., mode 3 user) or may be in transmission mode 4 (i.e., mode 4 user). A mode 3 user may directly use the resources allocated by a base station for the sidelink (SL) communication among vehicles or between a vehicle and a pedestrian. A mode 4 user may obtain a list of candidate resources allocated by a base station, and may select a resource among the candidate resources for its SL communication. Herein, user, UE, WTRU, and vehicle WTRU may equivalently and interchangeably refer to a vehicle.

[0076] FIG. 2 is a signaling diagram of an example sidelink WTRU information exchange procedure 200 for communication between a (vehicle) WTRU 201 and the gNB and/or eNB 202 for V2X sidelink transmissions, for example according to 5G NR V2X and/or LTE V2X. Once the WTRU 201 is camped on a cell associated with the gNB/eNB 202, the WTRU 201 may receive system information block (SIB) type 21 (SIB21) 204, which may contain V2X sidelink communication configuration. For example, SIB21 204 may include the *SL-V2X-ConfigCommon* information

element (IE), which may include, but is not limited to include, components *v2x-CommRxPool*, *v2x-CommTxPoolNormalCommon*, *v2-CommTxPoolExceptional*, and/or *v2x-InterFreqInfoList*. *v2x-InterFreqInfoList* may be a list of neighboring frequencies (e.g., up to seven neighboring frequencies) for V2X sidelink communications. The WTRU 201 may send, to gNB/eNB 202, sidelink WTRU information 206 in one or more messages. For example, as part of the sidelink WTRU information 206, the vehicle WTRU 201 may send message(s) to the gNB/eNB 202 indicating to the gNB/eNB 202 that the WTRU 201 is (or is not) interested in receiving V2X sidelink communication and/or requesting assignment and/or release of transmission resources for V2X sidelink communication. The WTRU 201 and gNB/eNB 202 may exchange one or more RRCConnectionReconfiguration messages 208, which may include the *SL-V2X-ConfigDedicated* IE. For example, the *SL-V2X-ConfigDedicated* IE may include, but is not limited to include, *commTxResources* and/or *v2x-InterFreqInfoList*.

[0077] Study items on NR V2X consider Uu-based sidelink resource allocation/reconfiguration to identify enhancements of the LTE Uu interface and NR Uu interface to control NR sidelink from the cellular network, and to identify enhancements of the NR Uu interface to control LTE sidelink communications from the cellular network. In the context of LTE V2X synchronization, when a WTRU is connected to an eNB, the WTRU may already have the cell timing. If the WTRU is not in coverage of the eNB, the WTRU may use a global navigation satellite system (GNSS) for the timing synchronization. When the WTRU cannot find timing from either the eNB or GNSS, the WTRU may rely on sidelink WTRUs for timing information. GNSS satellites have atomic oscillators providing a stable and accurate time reference. A GNSS receiver may track signals from multiple satellites and retrieve a local time reference with absolute error less than 1 μ s for Global Positioning System (GPS) receivers. For coordinated multi-point transmission, the residual error using GPS may be around 10 ns. GNSS may be used for frequency synchronization by phase-locking the local oscillator to the incoming signal and stabilizing the carrier frequency. For modern vehicles equipped with a GNSS receiver, GNSS solutions for synchronization may be used for V2X.

[0078] For example, for synchronization in V2X, a WTRU may receive sidelink synchronization signals (SLSS) on a sidelink from other WTRUs. The SLSS may include primary sidelink synchronization signals (PSSS), secondary sidelink synchronization signals (SSSS), and/or physical sidelink broadcast channel (PSBCH) signals, which may further include synchronization information. The WTRU may use the information carried in the SLSS to obtain timing information. A threshold used for synchronization measurement (e.g., Synch-Threshold) may be received in RRC signaling (e.g. *v2x-SyncConfig* and/or *SL-V2X-Preconfiguration* IEs).

[0079] The SLSS may include, but are not limited to include, any one or more of the following example signals: PSSS, SSSS, PSBCH, and/or demodulation reference signal (DMRS) for demodulating the PSBCH. For example, PSSS and SSSS may be transmitted in adjacent time slots in the same subframe. Sidelink-ID (SID) may be split into two sets. For example, SIDs in the range of {0, 1, ..., 167} may be reserved for in-coverage WTRUs (i.e., WTRUs that can receive a signal strong enough to connect with a cell associated with the eNB) and SIDs in the range of {168, 169, ..., 335} may be used for out-of-coverage WTRUs. The subframes used as radio resources to transmit SLSS and PSBCH may be configured by higher layers

[0080] NR V2X requirements may be different from LTE V2X requirements. For example, for NR V2X services to be able support higher bandwidth, reliability and higher density of vehicles and users, existing LTE SLSS may not be sufficient. The capacity of the sidelink channels may need to be increased. For example, LTE V2X may not include beam-centric design and thus the LTE SLSS may be enhanced for NR V2X using directional beams. For certain use cases such as vehicle platooning, different handling for the synchronization timing reference and coverage may be used. Hence, modifications to NR synchronization may be implemented in order to apply NR synchronization for NR V2X.

[0081] A platoon may comprise a group of WTRUs, and one of the WTRUs in the group may be configured, assigned or selected as platoon leader, and the other WTRUs may be referred to as platoon followers. The platoon leader may be responsible for managing the other WTRUs in the platoon. For example, the platoon leader may provide any of the following functions for one or more of the platoon followers: coordination between multiple WTRUs (platoon followers); unified synchronization timing reference; and/or scheduling of resources for other WTRUs. The platoon leader may be a platoon manager. FIG. 3 is a network diagram of an example vehicle platoon 300 including a platoon leader (PL) WTRU 302 (Hop 0), platoon follower WTRU 304 (Hop 1 because it is a neighbor to PL WTRU 302), platoon follower WTRU 306 (Hop 2 because it is two links away from PL WTRU 302), and a WTRU 301 that would like to join the vehicle platoon 300. As described further below, the WTRU 301 may use information (e.g., reference signal received power (RSRP), synchronization source type as leader or follower, hop #, threshold(s), and/or priority rules) based on the received SL synchronization signals PL SL-SYNC 310, H1 SL-SYNC 312 and H2 SL-SYNC 314 to select a synchronization source from among platoon member WTRUs 302, 304 and 306 in order to connect to the vehicle platoon 300. The methods disclosed herein are described for the application of a vehicle platoon as an example; any of the methods may be similarly applied to any application or use case involving a group of WTRUs (e.g., a mesh network, a relay network or any other group formation of WTRUs).

[0082] Methods of sidelink synchronization disclosed herein may be used in NR V2X for such use cases as vehicle platooning, and may also be used in other NR use cases. Any of the synchronization methods, access methods and/or signaling mechanisms described herein may be used by a WTRU to synchronize with a vehicle platoon in order to become a member of the vehicle platoon.

[0083] In an example, methods of sidelink synchronization may be based on measurement, measurement type and/or synchronization source type. A WTRU may synchronize with one of the synchronization sources in a vehicle platoon. For example, a WTRU may attempt to synchronize with a platoon leader first. In an example, the WTRU may fail to synchronize with the platoon leader (e.g., because the WTRU does not receive SLSS from the platoon leader or the SLSS from the platoon leader are too weak for the WTRU to properly decode). The WTRU may synchronize with one of the platoon followers if the WTRU fails to synchronize with the platoon leader. In an example, the WTRU may use signal measurement(s) to decide the source with which the WTRU may synchronize. For example, if a signal measurement from a synchronization source (e.g., a WTRU in the platoon) is above a threshold, the WTRU may synchronize with the synchronization source. Otherwise, the WTRU may choose to synchronize with another synchronization source. In an example, when multiple synchronization sources have signal measurements above a threshold, the WTRU may select the synchronization source with the highest measurement value.

[0084] In an of the example methods described herein, the configuration information for sidelink communications may be received from the eNB and/or from another WTRU (e.g., on a sidelink). For example, the configuration information for sidelink communications may be received in a SIB from the eNB. In any of the example methods described herein, the WTRU may search through synchronization sources by monitoring the sidelink channel(s) for signals from synchronization sources (e.g., members of the vehicle platoon). For example, the WTRU search through synchronization sources by monitoring sidelink channel(s) and receiving sidelink signals, such as any SLSS. In any of the example methods described herein, the WTRU may perform measurements on the same signals it received to search through the synchronization sources, or on different sidelink signals.

[0085] In any of the example methods described herein, types of measurements that may be performed by a WTRU for sidelink synchronization may include, but are not limited to include, any one or more of the following measurements: RSRP (equivalently sidelink RSRP (S-RSRP)), reference signal received quality (RSRQ) (equivalently sidelink RSRQ (S-RSRQ)), received signal strength indication (RSSI) (equivalently sidelink RSSI (S-RSSI)), signal-to-noise ratio (SNR),

correlation (equivalently SL correlation), and/or signal-to-interference-plus-noise ratio (SINR). Synchronization source selection may be based on any one or more of the different types of measurements made on signals received from synchronization sources (e.g., platoon leader and/or one or more platoon followers). In any of the example methods described herein, the WTRU may perform the measurements on signals received from the synchronization sources, such as SLSS (e.g., including the same signals it received when searching through the synchronization sources and/or different signals). In any of the example methods described herein, a SLSS may include a sidelink synchronization signal block (SL-SSB), such that the WTRU may perform measurements (e.g., RSRP) and any one or more parts of the SL-SSB. For example, the SL-SSB may include any of the following parts: PSSS, SSSS and/or a PSBCH signal. In this case, the WTRU may perform measurements on any one or more of the PSSS, SSSS and/or PSBCH signal. In another example, the SLSS may include reference signals, such as channel state information reference signals (CSI-RS) and/or PSBCH demodulation reference signals (DMRS). In this case, the WTRU may perform measurements on any one or more of the CSI-RS and/or PSBCH DMRS received in SLSS from one or more synchronization sources. In any of the example methods described herein, the measurements using CSI-RS and/or PSBCH DMRS may be performed independently from measurements using SL-SSB or in conjunction or in combination with SL-SSB.

[0086] In any of the example methods described herein, the synchronization source type may be one of platoon leader (and/or a platoon co-leader in the case that more than one WTRU may be platoon leader) or platoon follower. In any of the example methods described herein, the WTRU may determine the synchronization source type of a synchronization source based on information carried in (sidelink) signals received from the synchronization source. For example, the WTRU may determine the synchronization source type from information carried in any of the SLSS described above, and the synchronization source type may be implicitly or explicitly signaled. The WTRU may determine the synchronization source type from information carried in any of the SLSS used for measurement (and/or for searching through the synchronization sources) and/or from other SLSS received from the synchronization sources. For example, the SLSS (e.g., in the PSSS, SSSS, and/or PSBCH signal) may carry an explicit indication of source type (e.g., a bit where '1' indicates platoon leader, and '0' indicates a platoon follower). In another example, the SLSS (e.g., in the PSSS, SSSS, and/or PSBCH signal) may carry a hop number associated with the synchronization source (e.g., hop number equal to 0 indicates a platoon leader, and hop number greater than 0 indicates a platoon follower and equals the minimum number of links to the platoon leader), such that the WTRU may determine the synchronization source type implicitly from the hop number information carried in the SL-SSB. The hop number may be broadcasted using SL-SSB.

For example, the hop number may be broadcasted in PSBCH. The hop number may be included in information element in the PSBCH signal or carried in the payload of PSBCH signal. In this case, the WTRU may determine the synchronization source type implicitly from the hop number broadcasted in PSBCH. In another example, the hop number may be embedded in DMRS, which may be carried on the PSBCH. The WTRU may determine the synchronization source type implicitly from the hop number information carried in the DMRS of PSBCH. In another example, the hop number may be carried in the SPSS and/or SSSS and may be broadcasted in SPSS and/or SSSS in the SLSS. In this case, the WTRU may determine the synchronization source type implicitly from the hop number information carried in the SPSS and/or SSSS. The hop number may be broadcasted using any combination of PSBCH, DMRS, SPSS and/or SSSS (or other synchronization signals).

[0087] In an example, S-RSRP-based synchronization source selection alone does not take into account synchronization source type. For example, if a WTRU is closer to a platoon follower than a platoon leader, then S-RSRP from the platoon follower may be higher than S-RSRP from the platoon leader. If S-RSRP is the only criteria for synchronization source selection, then the WTRU may in some cases select a platoon follower over the platoon leader. In an example, the synchronization source type may also be considered as part of selection criteria for a synchronization source. For example, a platoon leader may have higher priority than platoon followers. In an example, when an S-RSRP measurement from a platoon leader and platoon followers are both above the threshold, even if S-RSRP of a platoon follower is higher than that of the platoon leader, the WTRU may select platoon leader rather than platoon follower. Therefore, synchronization source selection may depend on synchronization source type and measurements or measurement types (e.g., S-RSRP) and may be based on priorities between synchronization source type and measurements or measurement types.

[0088] In an example, the synchronization source selection may be based on any of the following criteria: measurements or measurement types (e.g., S-RSRP) measured from platoon leader or followers; synchronization source type (e.g., platoon leader type, platoon follower type); and/or priority and priority rules. FIG. 4 is a flow diagram of an example synchronization source selection method 400 based on measurement, measurement type and synchronization source type. The example synchronization source selection method 400 may be performed by a (vehicle) WTRU that wants to join a vehicle platoon. In the example synchronization source selection method 400, the synchronization source type is prioritized over the measurement (e.g., RSRP) value.

[0089] At 402, the WTRU may receive configuration information for sidelink communications, which may include at least a sidelink measurement threshold. For example, the

configuration information may be received in a SIB from the eNB. At 404, the WTRU may search through synchronization sources (e.g., by monitoring the sidelink for signals from synchronization sources and/or successfully receiving sidelink signals, such as SLSS, from synchronization sources). At 406, the WTRU may perform measurements (e.g., sidelink RSRP, sidelink correlation) on signals (e.g., SLSS) received from the synchronization sources. At 408, the WTRU may compile a list of synchronization sources (from among the “candidate” synchronization sources on which the WTRU took measurements) with measurement value(s) (e.g., measured RSRP) greater than the sidelink measurement threshold. At 410, for each of the synchronization sources in the list, the WTRU may check the synchronization source type (e.g., platoon leader or platoon follower). As described above, the synchronization source type may be determined based on implicit information (e.g., hop number) and/or explicit information (source type indication) carried in the SLSS received by the WTRU.

[0090] If a synchronization source type is platoon leader, then, at 412, the WTRU may select the platoon leader as the synchronization source and, at 414, establish a (side) link with the platoon leader so that the WTRU may obtain timing information from the platoon leader. Otherwise, if there is no synchronization source in the list that is a platoon leader type (i.e., all synchronization sources in the list are platoon followers), then, at 416, the WTRU may select the synchronization source in the list having the highest measurement value (e.g., the highest RSRP). In this case, at 418, the WTRU may establish a communication (side) link with the selected platoon follower so that the WTRU may obtain timing information from the platoon follower.

[0091] FIG. 5 is a flow diagram of an example synchronization source selection method 500 based on absolute and relative measurement, measurement type and synchronization source type. The example synchronization source selection method 500 may be performed by a (vehicle) WTRU that wants to join a vehicle platoon. In the example synchronization source selection method 500, the synchronization source type is prioritized over the measurement (e.g., RSRP) value. However, if a measurement value (e.g., RSRP) is very strong (i.e., above a second threshold that is higher than the first threshold), then the priority of synchronization source type may be downgraded and the synchronization source with the highest measurement value (e.g., highest RSRP) may be selected.

[0092] At 502, the WTRU may receive configuration information for sidelink communications including one or more sidelink measurement threshold(s). For example, the sidelink measurement threshold(s) may include a first sidelink measurement threshold and a second sidelink measurement threshold. At 504, the WTRU may search through synchronization sources. At 506, the WTRU may perform measurements (e.g., RSRP, correlation) on signals (e.g., SLSS)

received from the synchronization sources. At 508, the WTRU may compile a first list of synchronization sources (from among the synchronization sources on which the WTRU took measurements) with measurement values (e.g., measured RSRP) greater than a first sidelink measurement threshold and a second list of synchronization sources with measurement values (e.g., measured RSRP) greater than a second sidelink measurement threshold, where the second threshold is greater than the first threshold.

[0093] At 510, for each of the synchronization sources in the first second list, the WTRU may check the synchronization source type (e.g., platoon leader or platoon follower). If a synchronization source type is platoon leader, then, at 512, the WTRU may further check if the measurement value (e.g., measured RSRP) from platoon leader is above or below the second sidelink measurement threshold (i.e., whether or not the platoon leader is in the second list). If platoon leader's measurement value is above the second sidelink measurement threshold, then, at 514, the WTRU may select platoon leader as the synchronization source and, at 516, establish a communication (side) link with the platoon leader (so that the WTRU may obtain timing information from the platoon leader). If the platoon leader's measurement value is below the second sidelink measurement threshold, then, at 518, the WTRU may further check if the platoon followers' measurement values are above or below the second sidelink measurement threshold (i.e., if there are platoon followers on the second list). If the measurement value for all platoon followers is below the second sidelink measurement threshold, then, returning to 514, the WTRU may select the platoon leader as the synchronization source and, at 516, establish a communication (side) link with the platoon leader. If a platoon follower's measurement value is above the second sidelink measurement threshold (i.e., the platoon follower is on the second list), then, at 520, the WTRU may select the platoon follower with the highest measurement value (e.g., highest RSRP) as the synchronization source and, at 522, establish a communication (side) link with the selected platoon follower (so that the WTRU may obtain timing information from the platoon follower).

[0094] In an example, the first and second sidelink measurement thresholds used for the platoon leader may be the same or different from the first and second sidelink measurement thresholds used for the platoon followers. The thresholds may be configured, predetermined or indicated either semi-statically or dynamically. For example, the thresholds may be included in the configuration information, 502.

[0095] Another example synchronization source selection method may be based on measurement type, synchronization source type and/or number of hops. In the case that the measurement value (e.g., S-RSRP) measured based on sidelink signals from the platoon leader is below a threshold, measurement values (e.g., S-RSRP) measured based on one or more platoon

followers are above a threshold, then the WTRU may determine which platoon follower to select as the synchronization source. If one of the platoon followers has better a measurement value (e.g., S-RSRP) than the other platoon follower(s), the WTRU may select the platoon follower with the highest measurement value or S-RSRP (e.g., the platoon followers may all be the same synchronization source type). However, a platoon follower that is closer to the platoon leader (i.e., has a lower hop number), even with a lower measurement value (S-RSRP), may be selected as the synchronization source over another platoon follower with higher measurement value but further away from the platoon leader (i.e., has a greater hop number). Thus, in this example, the synchronization source selection may depend on the number of hops from the synchronization source (e.g., where the selected synchronization source is a platoon follower) to the platoon leader. If one platoon follower has less hops (e.g., one hop) to platoon leader while the other platoon followers have more hops (e.g., two hops or more) to the leader, then the WTRU may select the platoon follower with fewer hops even if the measurement value is lower (but above the acceptable threshold). Therefore, synchronization source selection may depend on number of hops from the synchronization source (or platoon follower) to the platoon leader in addition to measurement or measurement type and/or synchronization source type.

[0096] Thus, an example method for synchronization source selection may be based on the following: measurement or measurement type measured from the platoon leader or platoon followers; synchronization source type; and/or number of hops between the synchronization source (or platoon follower) and platoon leader.

[0097] FIG. 6 is a flow diagram of an example synchronization source selection method 600 based on measurement, measurement type, synchronization source type and number of hops. The example synchronization source selection method 600 may be performed by a (vehicle) WTRU that wants to join a vehicle platoon. In the example synchronization source selection method 600, the synchronization source type may have higher priority than measurement or measurement type (e.g., RSRP or S-RSRP). The number of hops may have higher priority than measurement or measurement type. Other priority may be used.

[0098] At 602, the WTRU may receive configuration information for sidelink communications including one or more sidelink measurement threshold(s). For example, the sidelink measurement threshold(s) may include a sidelink measurement threshold T1, a first hop number threshold H1 and/or a second hop threshold H2. In other example, any of the thresholds may be preconfigured at the WTRU or received via other signaling. At 604, the WTRU may search through synchronization sources. At 606, the WTRU may perform measurement (e.g., RSRP, correlation) on signals (e.g., SLSS) received from the synchronization sources. At 608, the WTRU

may compile a list of synchronization sources with measurement and/or measurement type (e.g., measured RSRP or S-RSRP) greater than measurement threshold T1 and/or number of hops less than the first hop threshold, H1 (e.g., this may be a combined list or a first list based on measurement and a second list based on number of hops). For example, the number of hops may count the hops between the synchronization source and the platoon leader, with the platoon leader as a reference point. For example, if the synchronization source is the platoon leader, then the number of hops may be zero. If the synchronization source is platoon follower, then number of hops may be one or greater than one corresponding to the minimum number of links between the synchronization source and the platoon leader.

[0099] At 610, the WTRU may check the synchronization source type for the synchronization sources in the list. If the type of a synchronization source is platoon leader, then, at 612, the WTRU may select the platoon leader as the synchronization source and, at 614, establish a communication (side) link with the platoon leader (so that the WTRU may obtain timing information from the platoon leader). Otherwise, if there is no synchronization source in the list that is a platoon leader type (i.e., all synchronization sources in the list are platoon followers), then, at 616, the WTRU may further compare the measurement value and/or measurement type (e.g., RSRP or S-RSRP) and number of hops among synchronization sources. At 618, the WTRU may determine for each synchronization source in the list if the number of hops (i.e., number of links to the platoon leader) is less than the second hop threshold H2. If the number of hops for one or more synchronization sources (platoon followers) is less than a second hop threshold H2, then, at 624, the WTRU may select that synchronization source (e.g., the platoon follower) among synchronization sources with number of hops less than a second hop threshold H2 with the highest measurement value (RSRP or S-RSRP) and, at 626, establish a link with the selected synchronization source. If the number of hops is more than a second hop threshold H2 for all the synchronizations sources among platoon followers, then, at 620, the WTRU may select any synchronization source (e.g., any platoon follower) with highest measurement values (e.g., highest RSRP) among synchronization sources with a number of hops that is less than a first hop threshold H1 (but not less than the second hop threshold H2) and, at 622, establish a link with the selected synchronization source with the highest measurement among synchronization sources with number of hops less than a first hop threshold H1 (but not less than the second hop threshold H2).

[00100] In another example, methods for sidelink synchronization source selection may be based on synchronization source type, number of hops, measurement type and/or link capacity. For example, if a platoon follower has fewer hops (to the platoon leader) but the link(s) between the platoon follower and the platoon leader is weak, then the platoon follower may not be selected even

if the measurement value (e.g., S-RSRP) measured from signals from the platoon follower are high. In this case, a synchronization source may be selected with a lower measurement value (e.g., S-RSRP) but with links between the platoon follower and platoon leader that have higher measurement (e.g., S-RSRP). Thus, in an example, the synchronization source selection method may depend on measurement and/or measurement type of links between the platoon follower and platoon leader in addition to the measurement and/or measurement type of the link measured from the platoon follower. For example, the synchronization source selection method may depend on number of hops from the synchronization source (e.g., platoon follower) to the platoon leader and the associated measurements and/or measurement types (e.g., S-RSRPs) that are associated with the hops/links in between the synchronization source and the platoon leader in addition to the measurements for the link between the WTRU and the synchronization source (platoon follower) and/or the synchronization source type.

[00101] An example synchronization source selection method may be based on any one or more of the following criteria: measurement and/or measurement type (e.g., S-RSRP) measured from platoon leader or followers; synchronization source type (e.g., platoon leader, platoon follower); number of hops between the synchronization source (or platoon follower) and platoon leader; and/or measurement and/or measurement type (e.g., S-RSRPs) associated with the hops between the synchronization source (e.g., platoon follower) and platoon leader.

[00102] FIG. 7 is a flow diagram of an example synchronization source selection method 700 based on measurement, measurement type and synchronization source type, number of hops and link capacity. The example synchronization source selection method 700 may be performed by a (vehicle) WTRU that wants to join a vehicle platoon. In the example synchronization source selection method 700, synchronization source type may have higher priority than measurement or measurement type (e.g., S-RSRP). The number of hops may have higher priority than measurement or measurement type. The link capacity may also have higher priority than measurement or measurement type. Other priority may be used.

[00103] At 702, the WTRU may receive configuration information for sidelink communications, which may include one or more sidelink measurement threshold(s), hop number threshold(s) and/or link capacity threshold(s). For example, the sidelink measurement threshold(s) may include a sidelink measurement threshold T1, a first hop number threshold H1, a second hop number threshold H2, and/or a link capacity threshold C. At 704, the WTRU may search through synchronization sources. At 706, the WTRU may perform measurement (e.g., RSRP, correlation) on signals (e.g., on PSSS, SSSS, and or PSBCH signal, which may be received as part of SLSS) received from the synchronization sources. At 708, the WTRU may compile a list of synchronization

sources with measurements (e.g., measured RSRP or S-RSRP) greater than sidelink measurement threshold T1 and/or number of hops less than the first hop threshold H1 and/or link capacity greater than capacity threshold C (e.g., this may be a combined list or separate lists such as a first list based on measurement, a second list based on number of hops and a third list based on link capacity). The link capacity may be associated the hops or links between the synchronization source and the platoon leader. The number of hops may be the hops between the synchronization source and the platoon leader, where the platoon leader has a number of hops equal to zero and a platoon follower has a number of hops greater than zero. In an example, the link capacity for a platoon follower with a path including one or more links to the platoon leader may be calculated as any of the following example capacity calculations: the individual link capacity (e.g., the capacity of the link in the path with the lowest capacity that forms the bottleneck); the averaged link capacity over all links in the path; or the total capacity summing the capacity for all links associated with the path of hops between the synchronization source and the platoon leader.

[00104] At 710, the WTRU may check the synchronization source type for the synchronization sources in the list. If the type of synchronization source is platoon leader, then, at 712, the WTRU may select the platoon leader as the synchronization source and, at 714, establish a communication (side) link with the platoon leader (so that the WTRU may obtain timing information from the platoon leader). Otherwise, if there is no synchronization source in the list that is a platoon leader type (i.e., all synchronization sources in the list are platoon followers), then, at 716, the WTRU may further compare the measurement value and/or measurement type (e.g., RSRP or S-RSRP) and number of hops among synchronization sources. At 718, the WTRU may determine for each synchronization source in the list if the number of hops (i.e., number of links to the platoon leader) is less than the second hop threshold H2. If the number of hops for one or more synchronization sources (platoon followers) is less than a second hop threshold H2, then, at 724, the WTRU may select that synchronization source (e.g., the platoon follower) among synchronization sources with number of hops less than a second hop threshold H2 with the highest measurement value (RSRP or S-RSRP) and, at 726, establish a link with the selected synchronization source. If the number of hops is more than a second hop threshold H2 for all the synchronizations sources among platoon followers, then, at 720, the WTRU may select any synchronization source (e.g., any platoon follower) with highest link capacity among synchronization sources with a number of hops that is less than a first hop threshold H1 (but not less than the second hop threshold H2) and, at 722, establish a link with the selected synchronization source with the highest link capacity among synchronization sources with number of hops less than a first hop threshold H1 (but not less than the second hop threshold H2).

[00105] In another example, synchronization source selection methods may be based on synchronization source type, number of hops, measurement type, link capacity and/or traffic load associated with links to platoon leader. For example, a method for synchronization source selection may be based on the following: measurement or measurement type (e.g., S-RSRP) measured from a platoon leader and/or platoon followers; synchronization source type (e.g., platoon leader type, platoon follower type); number of hops between the synchronization source and platoon leader; measurement and/or measurement type associated with links between the synchronization source and platoon leader; average measurement (e.g., average RSRP) associated with links between the synchronization source and platoon leader; link capacity associated with links between the synchronization source and platoon leader; and/or traffic load associated with links between the synchronization source and platoon leader.

[00106] FIG. 8 is a flow diagram of an example synchronization source selection method 800 based on measurement, measurement type, synchronization source type, number of hops, link capacity, and traffic load. The example synchronization source selection method 800 may be performed by a (vehicle) WTRU that wants to join a vehicle platoon. In the example synchronization source selection method 800, synchronization source type may have higher priority than measurement or measurement type (e.g., S-RSRP). The number of hops may have higher priority than measurement or measurement type. The link capacity and/or traffic load may have higher priority than measurement or measurement type. Other priority may be used.

[00107] At 802, the WTRU may receive configuration information for sidelink communications, which may include one or more sidelink measurement threshold(s), hop number threshold(s) and/or link capacity threshold(s). For example, the sidelink measurement threshold(s) may include a sidelink measurement threshold T1, a first hop number threshold H1, a second hop threshold H2, and/or a link capacity threshold C. At 804, the WTRU may search through synchronization sources. At 806, the WTRU may perform measurement (e.g., RSRP, correlation) on signals (e.g., on PSSS, SSSS, and or PSBSC signal, which may be received as part of SLSS) received from the synchronization sources. At 808, the WTRU may compile a list of synchronization sources with measurements (e.g., measured RSRP or S-RSRP) greater than sidelink measurement threshold T1 and/or number of hops less than the first hop threshold H1 and/or link capacity greater than capacity threshold C (e.g., this may be a combined list or separate lists such as a first list based on measurement, a second list based on number of hops and a third list based on link capacity). The link capacity may be associated the hops or links between the synchronization source and the platoon leader. The number of hops may be the hops between the synchronization source and the platoon leader, where the platoon leader has a number of hops equal to zero and a

platoon follower has a number of hops greater than zero. In an example, the link capacity for a platoon follower with a path including one or more links to the platoon leader may be calculated as any of the following example capacity calculations: the individual link capacity (e.g., the capacity of the link in the path with the lowest capacity that forms the bottleneck); the averaged link capacity over all links in the path; or the total capacity summing the capacity for all links associated with the path of hops between the synchronization source and the platoon leader. In an example, the traffic load may be calculated over the links between the synchronization source and the platoon leader.

[00108] At 810, the WTRU may check the synchronization source type for the synchronization sources in the list. If the type of synchronization source is platoon leader, then, at 712, the WTRU may select the platoon leader as the synchronization source and, at 714, establish a communication (side) link with the platoon leader (so that the WTRU may obtain timing information from the platoon leader). Otherwise, if there is no synchronization source in the list that is a platoon leader type (i.e., all synchronization sources in the list are platoon followers), then, at 816, the WTRU may further compare signal measurement value (e.g., RSRP), and number of hops (and/or link capacity and/or traffic load) associated with hops/links among synchronization sources. At 818, the WTRU may determine for each synchronization source in the list if the number of hops (i.e., number of links to the platoon leader) is less than the second hop threshold H2. If the number of hops is less than a second hop threshold H2, then, at 824, the WTRU may select the synchronization source (e.g., the platoon follower) among synchronization sources with a number of hops less than a second hop threshold H2 and the lowest traffic load and, at 826, establish a link with the selected synchronization source. If the number of hops is more than a second hop threshold H2 for all the synchronizations sources among platoon followers, then, at 820, the WTRU may select any synchronization source (e.g., any platoon follower) with highest link capacity among synchronization sources with a number of hops that is less than a first hop threshold H1 (but not less than the second hop threshold H2) and, at 822, establish a link with the selected synchronization source with the highest link capacity among synchronization sources with number of hops less than a first hop threshold H1 (but not less than the second hop threshold H2).

[00109] FIG. 9 is a flow diagram of an example synchronization source selection method 900 based on measurement, measurement type and synchronization source type, and number of hops. The example synchronization source selection method 900 may be performed by a (vehicle) WTRU that wants to join a vehicle platoon. At 902, the WTRU may receive configuration information for sidelink communications, which may include sidelink measurement threshold(s), hop number thresholds, and/or link capacity thresholds. For example, the sidelink configuration information may include a first sidelink measurement threshold T1, a second sidelink measurement threshold T2,

and a hop count (hop number) threshold H. In an example, the second sidelink measurement threshold T2 is greater than the first sidelink measurement threshold T1.

[00110] At 904, the WTRU may search through synchronization sources. At 906, the WTRU may perform measurements (e.g., RSRP, correlation) on signals (e.g., SLSS) received from the synchronization sources. At 908, the WTRU may determine the synchronization source type for each of the synchronization sources, and at 909 the WTRU may determine the hop number for each of the synchronization sources. In an example, the WTRU may determine the synchronization source type and/or hop number of each synchronization source based on information carried in SLSS received from the respective synchronization source, for example based on information carried in the SPSS, SSSS and/or PSBCH signal. In an example, the SPSS, SSSS and/or PSBCH signal may carry a synchronization source type indicator that explicitly indicates to the WTRU the synchronization source type (e.g., platoon leader type or platoon follower type). In an example, the SPSS, SSSS and/or PSBCH signal may carry a hop number field that indicates to the WTRU the number of hops or links between the synchronization source and the platoon leader. In an example, the SLSS may not include synchronization source type indicator and the WTRU may determine the synchronization source type for each synchronization source based on the hop number field received in the SLSS (e.g., hop number equal to 0 indicates a platoon leader, and hop number greater than 0 indicates a platoon follower).

[00111] At 910, the WTRU may compile a list of synchronization sources (from among the synchronization sources on which the WTRU took measurements) with measurement value (e.g., measured RSRP) greater than a first sidelink measurement threshold T1. At 912, the WTRU may consider the synchronization source type for the synchronization sources in the list. If the type of a synchronization source is platoon leader, then, at 914, the WTRU may select the platoon leader as the synchronization source and, at 916, establish a communication (side) link with the platoon leader (so that the WTRU may obtain timing information from the platoon leader). Otherwise, if there is no synchronization source in the list that is a platoon leader type (i.e., all synchronization sources in the list are platoon followers), then, at 918, the WTRU may further compare the hop numbers for the synchronization sources. At 920, the WTRU may determine for each synchronization source in the list if the number of hops (i.e., number of links to the platoon leader) is less than the hop threshold H. If the number of hops is less than the hop threshold H, then, at 924, the WTRU may select the synchronization source (e.g., the platoon follower) among synchronization sources with a number of hops less than the hop threshold H and, at 916, establish a link with the selected synchronization source (in this case, a platoon follower). If the number of hops is more than the hop threshold H for all the synchronizations sources among platoon followers, then, at 922,

the WTRU may select a synchronization source (platoon follower) with a measurement value (e.g., measured RSRP) greater than the second measurement threshold T2 and, at 916, establish a link with the selected synchronization source (in this case, a platoon follower).

[00112] In another example, methods for sidelink synchronization and source selection may be based on any one or more of source type, number of hops, numerology (e.g., subcarrier spacing (SCS), cyclic prefix (CP)), bandwidth part (BWP), link capacity and/or traffic load (associated with hops between the synchronization source and the platoon leader). A WTRU may receive sidelink configuration information, which may include one or the threshold(s) corresponding to measurement, number of hops, link capacity, and/or traffic load. Methods for sidelink synchronization and source selection may be based on any of the following criteria: measurement and/or measurement type (e.g., S-RSRP or RSRP) measured from platoon leader or follower; synchronization source type (e.g., platoon leader type, platoon follower type); number of hops between the synchronization source or platoon follower and platoon leader; measurement and/or measurement type (e.g., S-RSRP) associated with hops or path of hops between the synchronization source or platoon follower and platoon leader; average measurement (e.g., averaged S-RSRP) associated with hops between the synchronization source or platoon follower and platoon leader; link capacity associated with hops and/or the path of hops between the synchronization source or platoon follower and platoon leader; traffic load associated with hops and/or path of hops between the synchronization source or platoon follower and platoon leader; bandwidth associated with hops and/or the path of hops between the synchronization source or platoon follower and platoon leader; numerology associated with hops and/or the path of hops between the synchronization source or platoon follower and platoon leader; number of resource blocks associated with hops and/or the path of hops between the synchronization source or platoon follower and platoon leader; and/or number of bandwidth parts (BWPs) associated with hops and/or the path of hops between the synchronization source or platoon follower and platoon leader. Different combinations and/or priorities of selection criteria may be applied to the information or parameters above to optimize the synchronization including sidelink synchronization for V2X.

[00113] Methods may be used for sidelink synchronization assistance information communications. Synchronization assistance information may include any one or more of the following information: the measurement and/or measurement type; synchronization source type; number of hops or hop order: average or total measurement (e.g., S-RSRP) associated with hops or path of hops; link capacity associated with hops or path of hops; and/or traffic load associated with hops or path of hops. For example, any of the following information may be gathered by or signaled to the WTRU: measurement and/or measurement type (e.g., S-RSRP or RSRP) measured from

platoon leader or platoon followers; synchronization source type (e.g., platoon leader type, platoon follower type); number of hops between the synchronization source and platoon leader; measurement and/or measurement type (e.g., S-RSRPs) associated with hops and/or path of hops between the synchronization source and platoon leader; average and/or total measurement and/or measurement type (e.g., S-RSRP) associated with hops and/or path of hops between the synchronization source (e.g., platoon follower) and platoon leader; capacity associated with hops and/or path of hops between the synchronization source and platoon leader; and/or load associated with hops and/or path of hops between the synchronization source and platoon leader.

[00114] In an example, the following information may be broadcasted or communicated to WTRUs for V2X sidelink synchronization source selection: measurement and/or measurement type (e.g., S-RSRP); number of hops or hop order from synchronization source to platoon leader; capacity associated with the path of hops; traffic load associated with the path of hops; numerology associated with the path of hops; BWP information associated with the path of hops; and/or priority including synchronization source priority. For example, the hop number, synchronization source type and/or synchronization source priority may be broadcasted from one WTRU to other WTRUs. The WTRU may determine and select the synchronization source based on any one or more of the hop number, synchronization source type, and/or synchronization source priority.

[00115] A platoon leader (or any WTRU including a platoon follower) may communicate synchronization assistance information to a WTRU. For example, a platoon leader may broadcast, groupcast or unicast the synchronization assistance information to one, multiple or all WTRUs. A WTRU may report the information related to synchronization assistance information to the platoon leader. The platoon leader may aggregate all the information reported from the WTRUs and convert the received information into a set of synchronization assistance information and communicate the updated synchronization assistance information back to the WTRUs.

[00116] Example methods may be used for communicating the synchronization assistance information to the WTRUs. For example, an NR physical sidelink control channel (NR-PSCCH) may be used to communicate synchronization assistance information to WTRUs. In another example, SLSS or PSBCH may be used to send the synchronization assistance information to WTRUs. In another example, a sidelink group common control channel, which may be a physical downlink control channel (PDCCH) (e.g., SL-GC-PDCCH) may be used to send synchronization assistance information to WTRUs. In another example, a group common control physical sidelink control channel (GC-SL-PSCCH or GC-PSCCH) or a group common control physical sidelink shared channel (GC-SL-PSSCH or GC-PSSCH) may be used, and may be groupcast, unicast or broadcast, or transmitted on-demand.

[00117] In another example, sidelink system information may be used. Sidelink system information may include sidelink remaining minimum system information (SL-RMSI) and/or sidelink other system information (SL-OSI), which may be broadcast, groupcast, unicast or transmitted on-demand. In another example, sidelink random access channel (SL-RACH) may be used. SL-RACH may include two-step or four-step RACH approach. For example, sidelink message 1 (SL-MSG1) and/or message 2 (SL-MSG2) may be used in a two-step RACH approach. Additionally, sidelink message 3 (SL-MSG3) and/or message 4 (SL-MSG4) may be used in a four-step RACH approach. SL-RACH may be used to request the synchronization assistance information for broadcast, groupcast, unicast or on-demand for synchronization assistance information. SL-RACH may be used to send the synchronization assistance information via broadcast, groupcast, unicast or on-demand.

[00118] In an example, synchronization information may be partitioned into two (or more) sets, for example the first synchronization assistance information and the second synchronization assistance information. The second synchronization assistance information may have higher priority than the first synchronization assistance information. Additional priority rules may be applied to each set of synchronization assistance information. For example, one set of priority rules may be used within the first synchronization assistance information. Another set of priority rules may be used for the second synchronization assistance information.

[00119] The first synchronization assistance information may be delivered in a semi-static or dynamic manner and the second synchronization assistance information may be delivered in a dynamic manner (or semi-static manner). In an example, the second synchronization assistance information may override the first synchronization assistance information. An override indicator may be carried in the synchronization assistance information. For example, an override indicator may be carried in the second synchronization assistance information. When the WTRU receives the second synchronization assistance information, the WTRU may check the override indicator. If the override indicator indicates override or "on", the WTRU may replace the first synchronization assistance information with the second synchronization assistance information. The WTRU may use the second synchronization assistance information for synchronization source selection. If the override indicator indicates "non-override" or "off", the WTRU may append the second synchronization assistance information to the first synchronization assistance information. In this case, the WTRU may use both the first and the second synchronization assistance information for assisting synchronization source selection.

[00120] The first synchronization assistance information and the second synchronization assistance information may be delivered in different periodicities, resources and/or via different

signals or channels. For example, the first synchronization assistance information may be delivered in less frequently (e.g., with a greater periodicity) while the second synchronization assistance information may be delivered more frequently (e.g., with a smaller periodicity). The first synchronization assistance information may be delivered using NR-PSCCH while the second synchronization assistance information may be delivered using SL-GC-PDCCH. In another example, the first synchronization assistance information may be delivered using PSSS, SSSS and/or PSBCH while the second synchronization assistance information may be delivered using PSCCH or SL-GC-PDCCH. The first synchronization assistance information may be delivered in a periodic manner while the second synchronization assistance information may be delivered in an aperiodic manner or event triggered manner. Different combinations above may be to optimize the V2X sidelink synchronization.

[00121] FIG. 10 is a flow diagram of an example synchronization assistance information method 1000 for NR V2X sidelink, which may be performed by a WTRU that is a member of a vehicle platoon. At 1002, WTRU may receive sidelink synchronization configuration. At 1004, the WTRU may receive the first sidelink synchronization assistance information. At 1006, the WTRU may receive priority rules for the first sidelink synchronization parameters. At 1008, the WTRU may receive the second sidelink synchronization assistance information. At 1010, the WTRU may receive priority rules for the second sidelink synchronization parameters. At 1012, the WTRU may select the synchronization source based on the synchronization assistance information and priority rules associated with the first and second synchronization assistance information. Synchronization methods and synchronization source selection methods for V2X sidelink may be based any combination, subset of subcomponent of the methods and techniques described herein.

[00122] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency

transceiver for use in a WTRU, WTRU, terminal, base station, RNC, or any host computer.

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CLAIMS

What is claimed is:

1. A wireless transmit/receive unit (WTRU) configured to select a synchronization source in a vehicle platoon, the WTRU comprising:

a transceiver; and

a processor, wherein

the transceiver is configured to receive configuration information for sidelink communications, wherein the configuration information includes at least a first sidelink measurement threshold, a second sidelink measurement threshold and a first hop number threshold;

the transceiver is configured to monitor at least one sidelink channel for signals from a plurality of synchronization sources, wherein the synchronization sources are WTRUs in the vehicle platoon;

the transceiver is configured to perform a sidelink measurement on a sidelink synchronization signal from each of the plurality of synchronization sources;

the processor is configured to determine synchronization source type and hop number for each of the plurality of synchronization sources based on information carried in the respective sidelink synchronization signal;

the processor is configured to compile a list of synchronization sources from the plurality of synchronization sources for which a value of the sidelink measurement is greater than the first sidelink measurement threshold;

the processor is configured to, on a condition that a synchronization source in the list of synchronization sources is a platoon leader synchronization source type, select the synchronization source with platoon leader type;

the processor is configured to, on a condition that no synchronization source in the list of synchronization sources is a platoon leader synchronization source type:

on a condition that a synchronization source in the list of synchronization sources has a hop number less than the first hop number threshold, select the synchronization source with hop number less than the first hop number threshold;

on a condition that no synchronization source in the list of synchronization sources has a hop number less than the first hop number threshold, select the synchronization source for which the value of the sidelink measurement is greater than the second sidelink measurement threshold; and

the transceiver is configured to establish a link with the selected synchronization source.

2. The WTRU of claim 1, wherein the configuration information is received in a system information block (SIB) from an evolved Node B (eNB).

3. The WTRU of claim 1, wherein the configuration information further includes a first link capacity threshold.

4. The WTRU of claim 1, wherein the transceiver is configured to perform sidelink measurement according to at least one of: reference signal received power (RSRP), reference signal received quality (RSRQ), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR) or correlation.

5. The WTRU of claim 1, wherein the information carried in the sidelink synchronization signals includes a synchronization source type indicator indicating one of a platoon leader type and a platoon follower type, and the processor is configured to determine the synchronization source type for each of the plurality of synchronization sources based on the synchronization source type indicator.

6. The WTRU of claim 1, wherein the information carried in the sidelink synchronization signals includes a hop number field indicating a number of links between the synchronization source and a platoon leader, and the processor is configured to determine the hop number for each of the plurality of synchronization sources based on the hop number field.

7. The WTRU of claim 6, wherein the processor is configured to determine the synchronization source type for each of the plurality of synchronization sources based on the hop number field, such that a hop number of 0 indicates a platoon leader type and a hop number greater than zero indicates a platoon follower type.

8. The WTRU of claim 1, wherein the sidelink synchronization signals comprise at least one of the following signals: a primary sidelink synchronization signal (PSSS), a secondary sidelink synchronization signal (SSSS), a signal carried on a physical sidelink broadcast channel (PSBCH), a sidelink synchronization signal block (SL-SSB), a channel state information reference signal (CSI-RS), or PSBCH demodulation reference signal (PSBCH-DMRS).

9. The WTRU of claim 1, wherein the transceiver is further configured to receive signals comprising timing information from the selected synchronization source.

10. The WTRU of claim 1 configured as a vehicle WTRU.

11. A method, performed by wireless transmit/receive unit (WTRU), for selecting a synchronization source in a vehicle platoon, the method comprising:

receiving configuration information for sidelink communications, wherein the configuration information includes at least a first sidelink measurement threshold, a second sidelink measurement threshold and a first hop number threshold;

monitoring at least one sidelink channel for signals from a plurality of synchronization sources, wherein the synchronization sources are WTRUs in the vehicle platoon;

performing a sidelink measurement on a sidelink synchronization signal from each of the plurality of synchronization sources;

determining synchronization source type and hop number for each of the plurality of synchronization sources based on information carried in the respective sidelink synchronization signal;

compiling a list of synchronization sources from the plurality of synchronization sources for which a value of the sidelink measurement is greater than the first sidelink measurement threshold;

on a condition that a synchronization source in the list of synchronization sources is a platoon leader synchronization source type, selecting the synchronization source with platoon leader type;

on a condition that no synchronization source in the list of synchronization sources is a platoon leader synchronization source type:

on a condition that a synchronization source in the list of synchronization sources has a hop number less than the first hop number threshold, selecting the synchronization source with hop number less than the first hop number threshold;

on a condition that no synchronization source in the list of synchronization sources has a hop number less than the first hop number threshold, selecting the synchronization source for which the value of the sidelink measurement is greater than the second sidelink measurement threshold; and

establishing a link with the selected synchronization source.

12. The method of claim 11, wherein the configuration information is received in a system information block (SIB) from an evolved Node B (eNB).

13. The method of claim 11, wherein the configuration information further includes a first link capacity threshold.

14. The method of claim 11, wherein the performing sidelink measurement is according to at least one of: reference signal received power (RSRP), reference signal received quality (RSRQ), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR) or correlation.

15. The method of claim 11, wherein the information carried in the sidelink synchronization signals includes a synchronization source type indicator indicating one of a platoon leader type and a platoon follower type, and the determining the synchronization source type for each of the plurality of synchronization sources is based on the synchronization source type indicator.

16. The method of claim 11, wherein the information carried in the sidelink synchronization signals includes a hop number field indicating a number of links between the synchronization source and a platoon leader, and the determining the hop number for each of the plurality of synchronization sources based on the hop number field.

17. The method of claim 16, wherein the determining the synchronization source type for each of the plurality of synchronization sources is based on the hop number field, such that a hop number of 0 indicates a platoon leader type and a hop number greater than zero indicates a platoon follower type.

18. The method of claim 11, wherein the sidelink synchronization signals comprise at least one of the following signals: a primary sidelink synchronization signal (PSSS), a secondary sidelink synchronization signal (SSSS), a signal carried on a physical sidelink broadcast channel (PSBCH), a sidelink synchronization signal block (SL-SSB), a channel state information reference signal (CSI-RS), or PSBCH demodulation reference signal (PSBCH-DMRS).

19. The method of claim 11, further comprising:

receiving signals comprising timing information from the selected synchronization source.

20. The method of claim 11, wherein the WTRU is a vehicle WTRU.

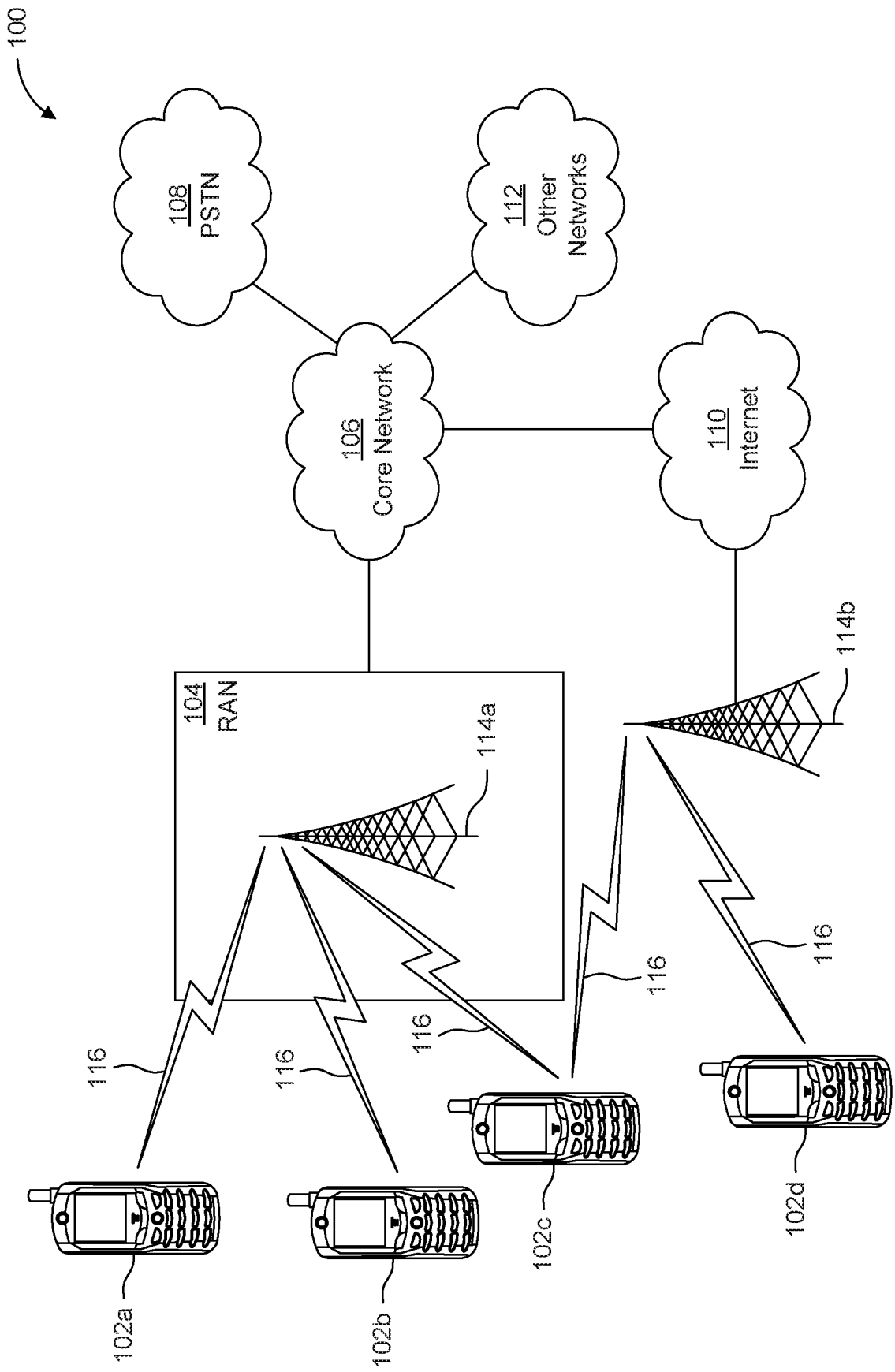


FIG. 1A

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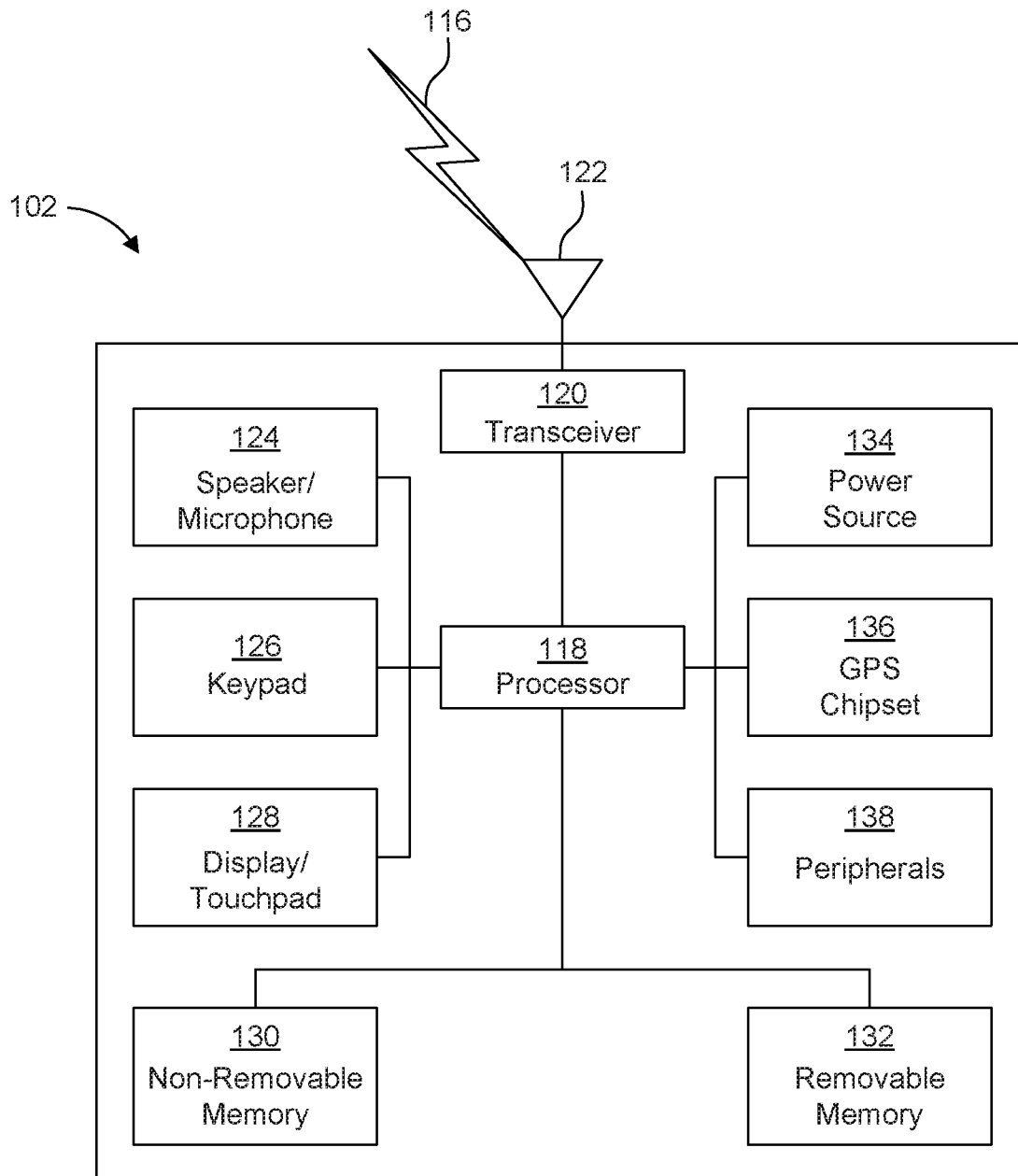


FIG. 1B

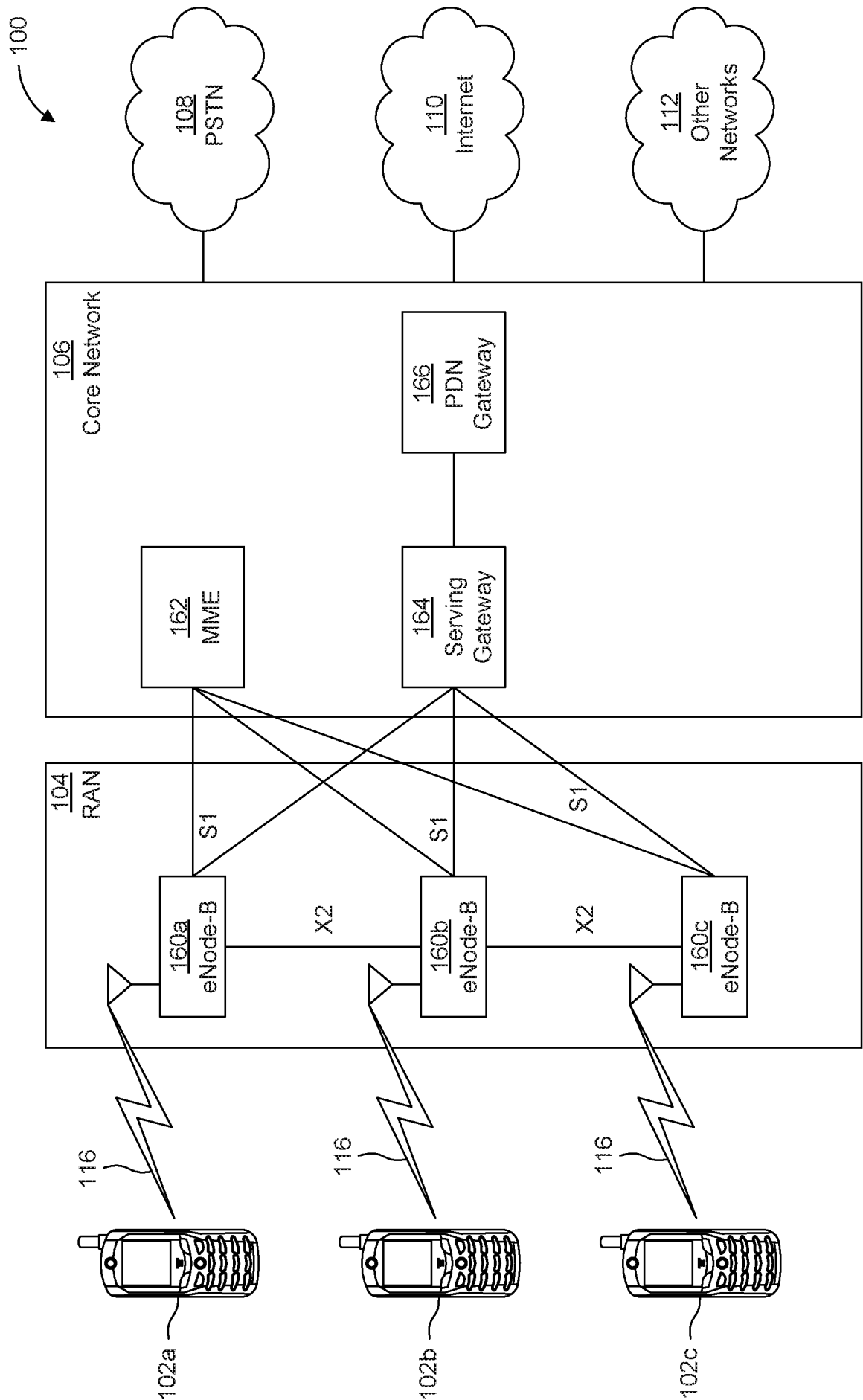


FIG. 1C

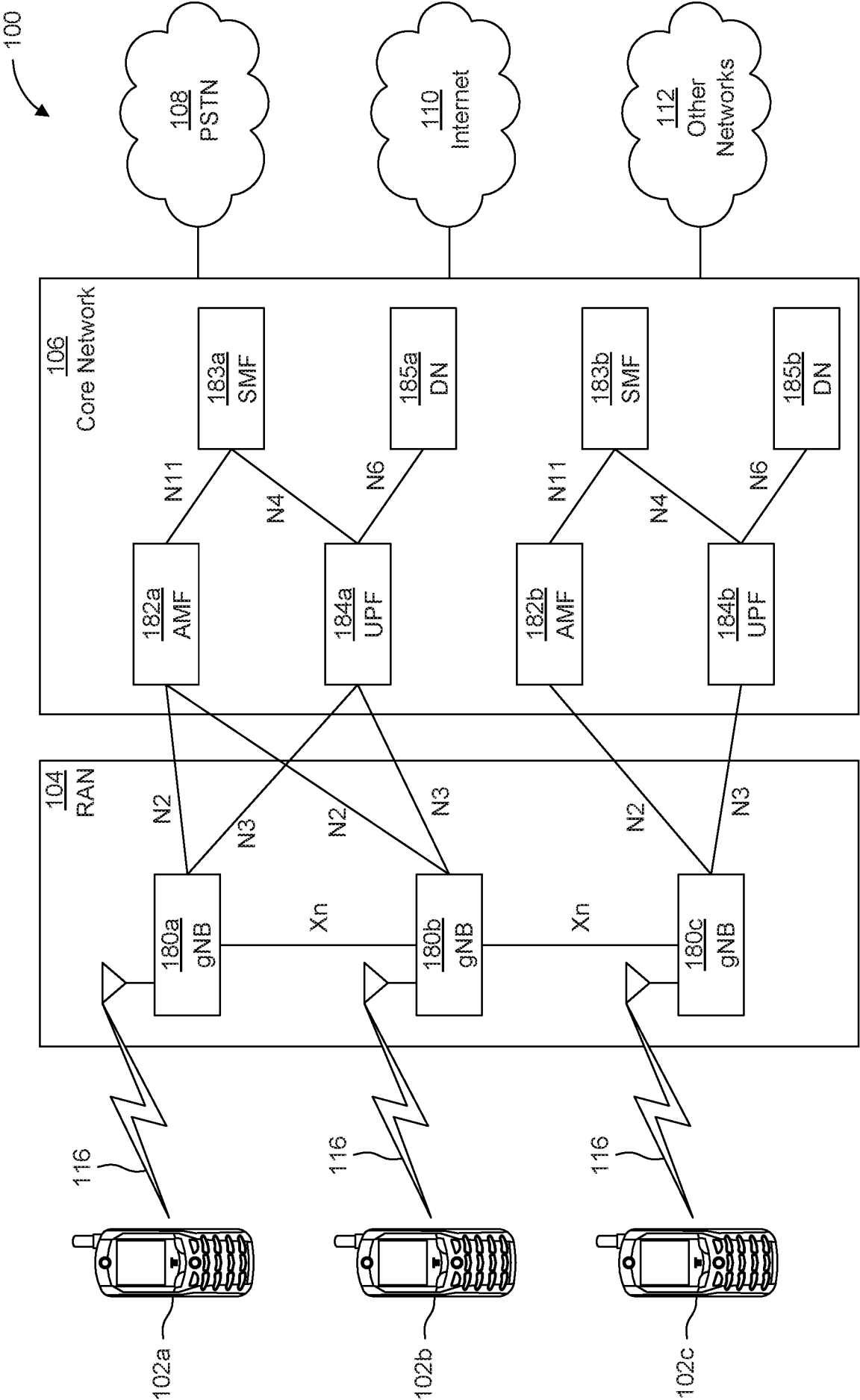


FIG. 1D

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200

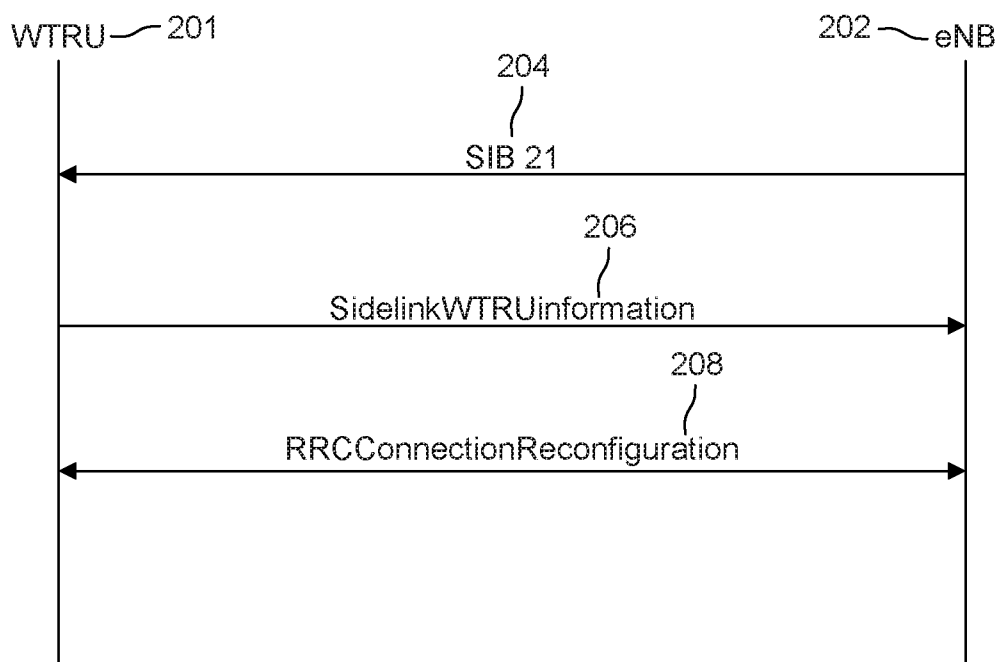


FIG. 2

300

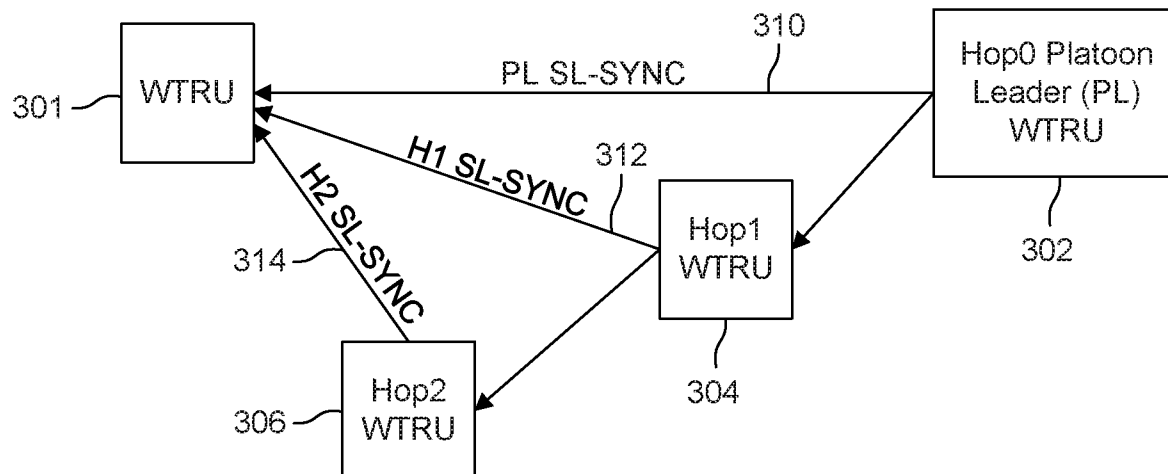


FIG. 3

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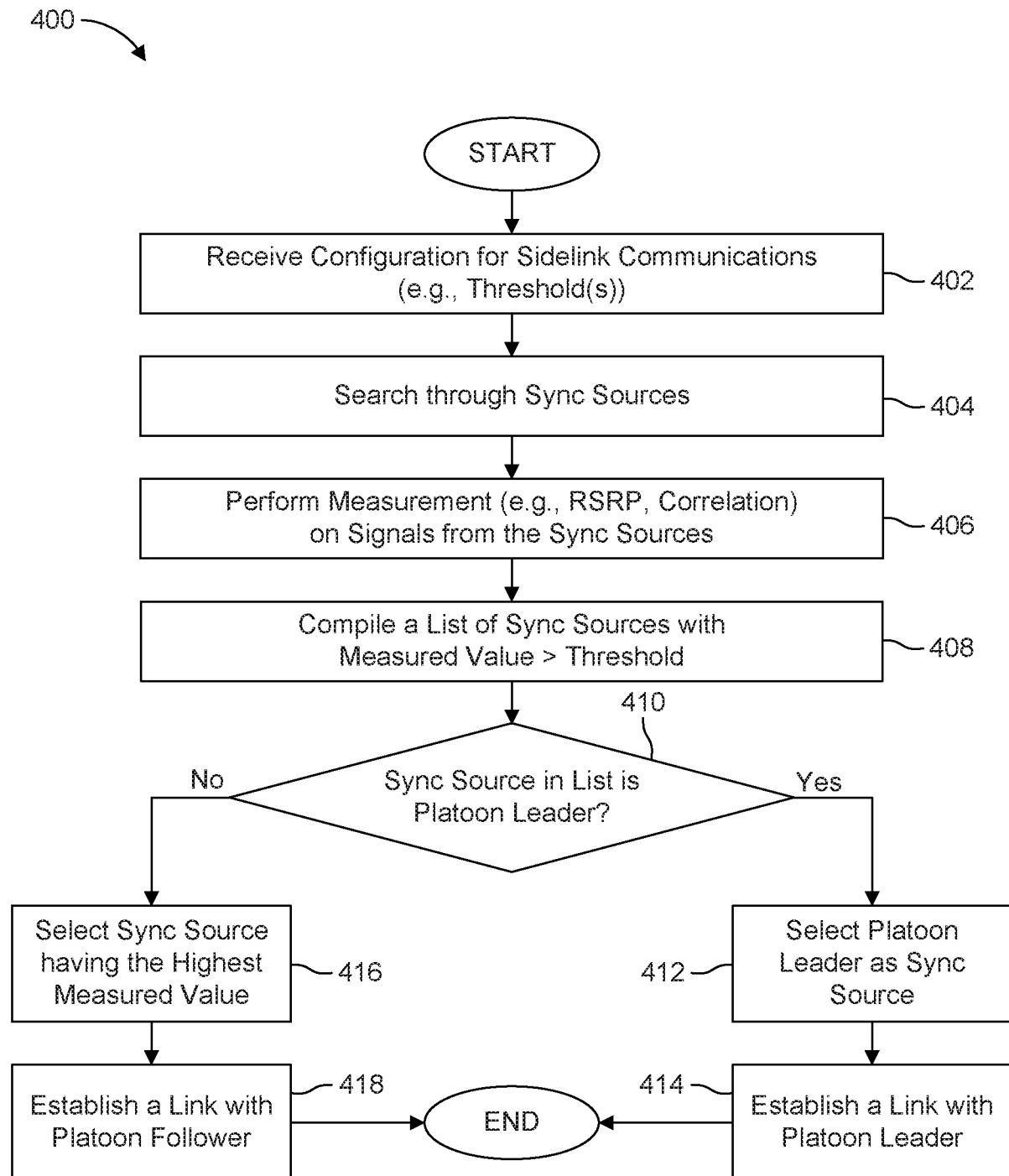


FIG. 4

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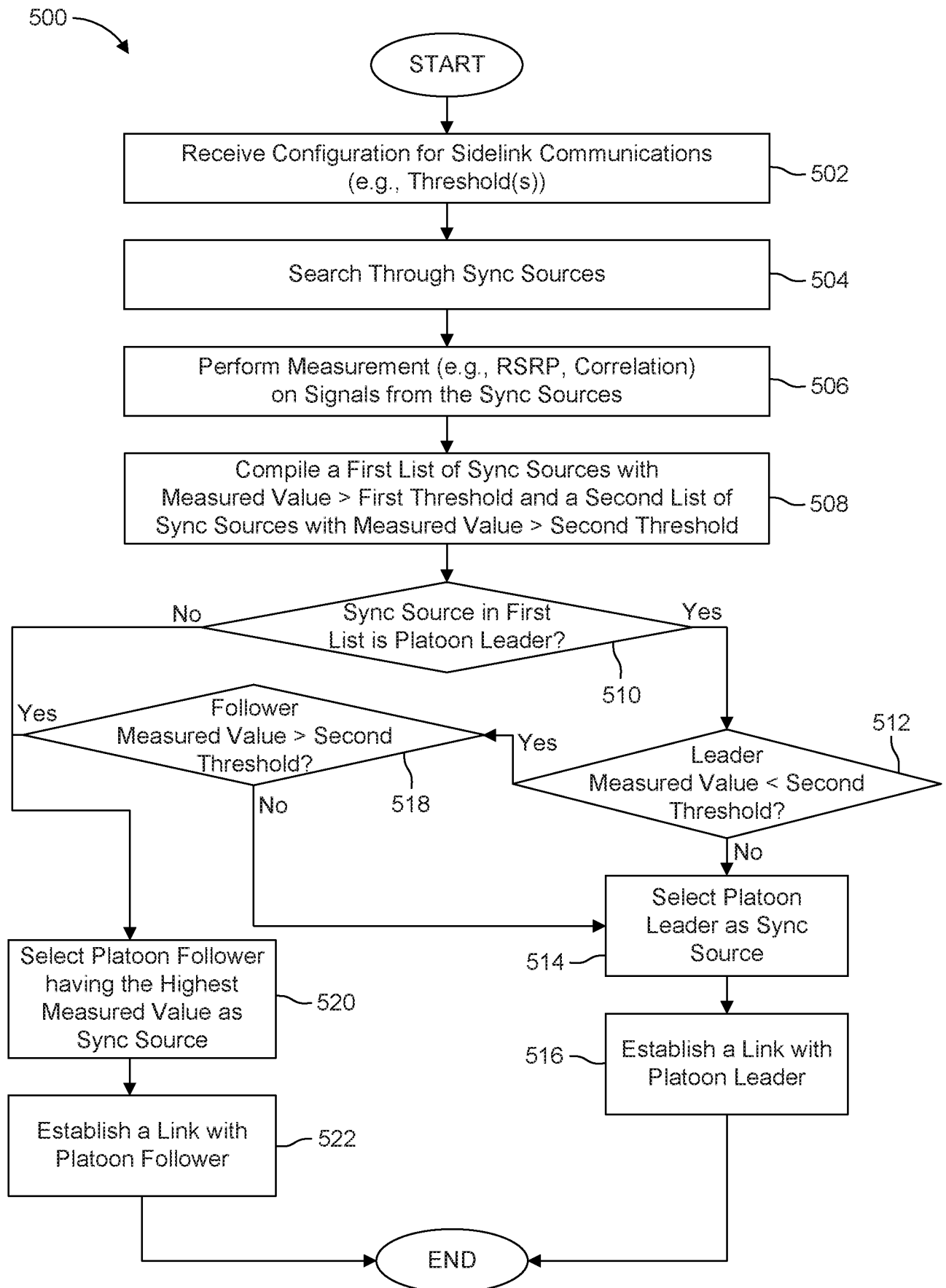


FIG. 5

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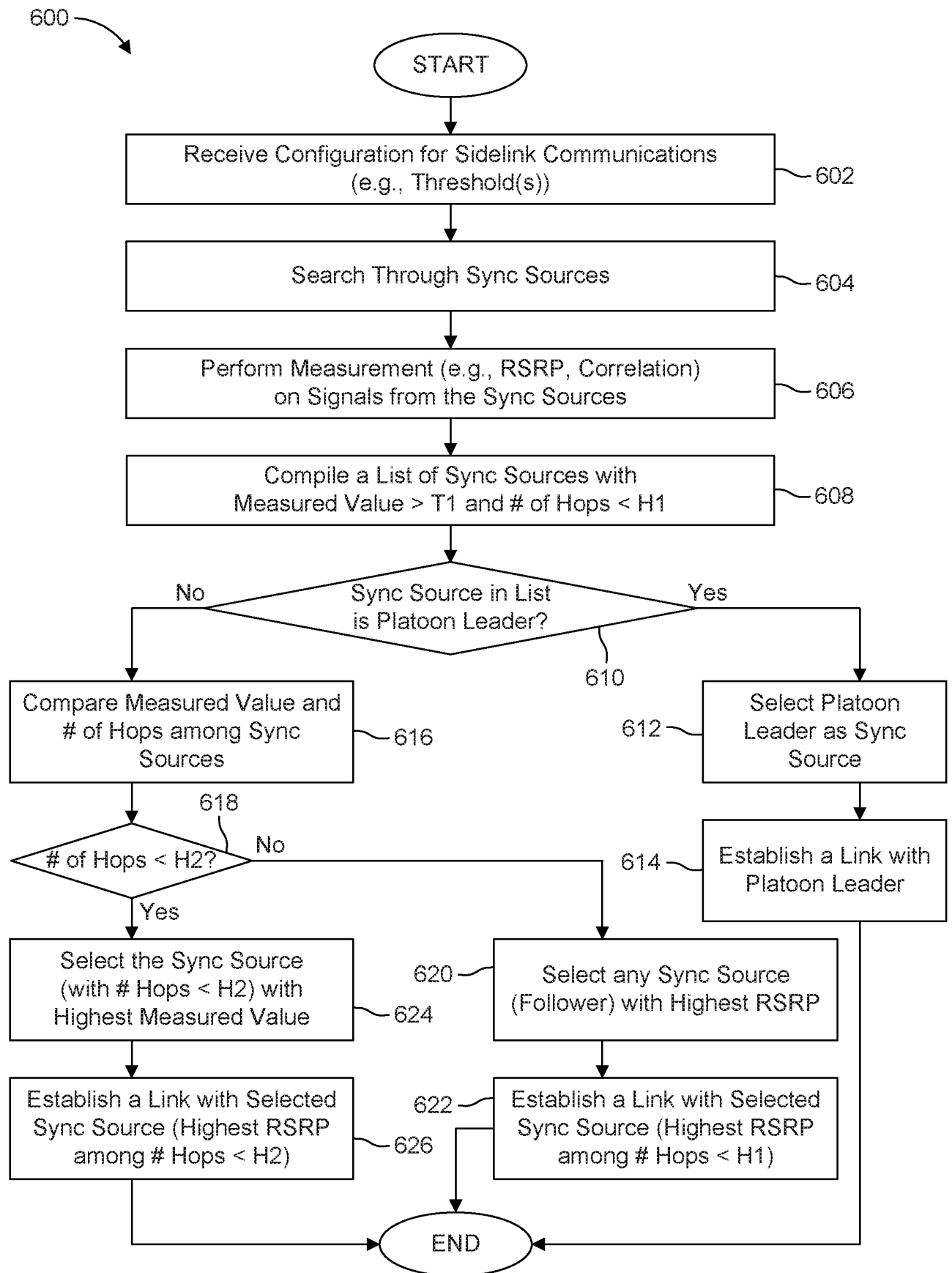
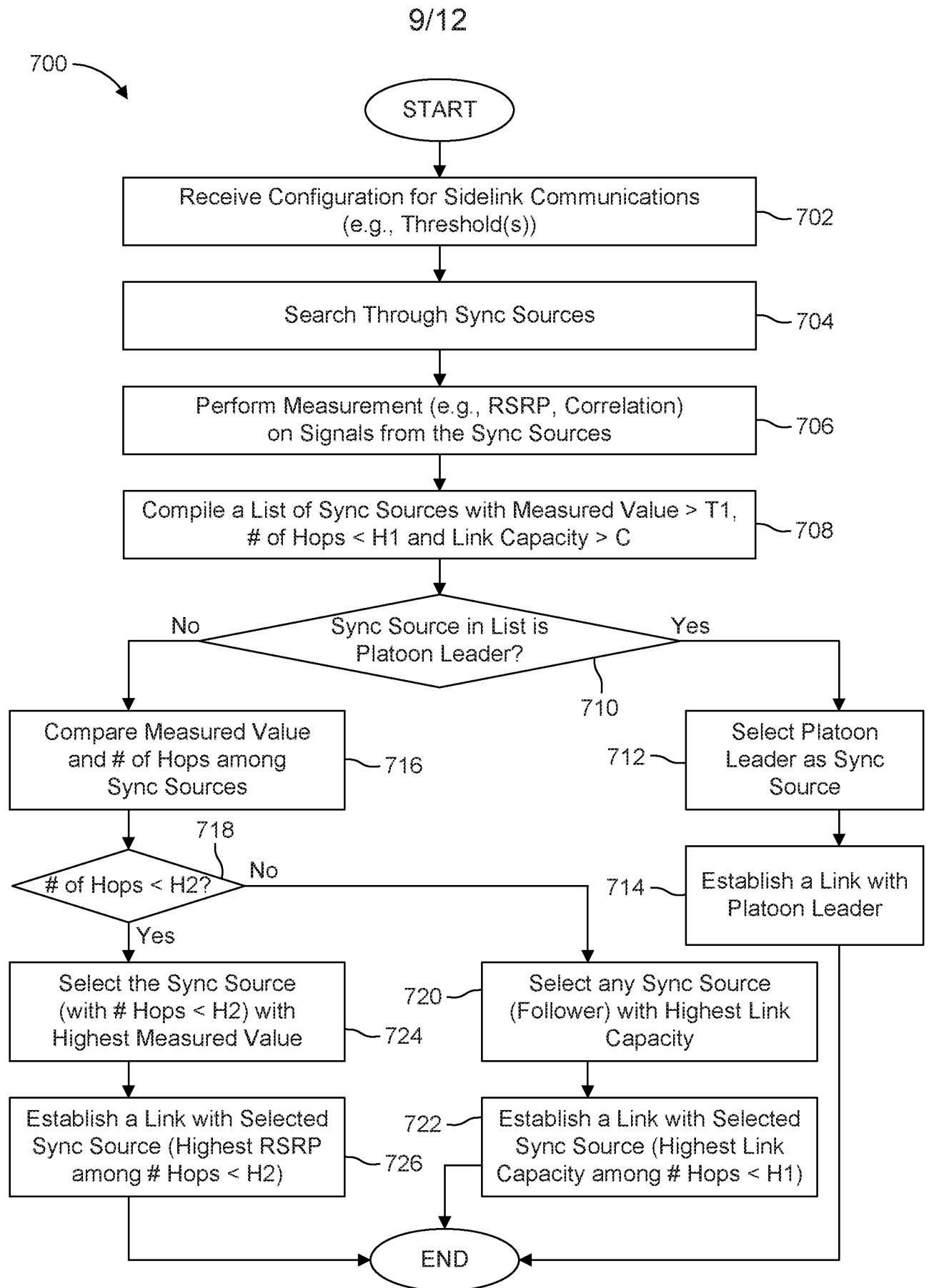


FIG. 6



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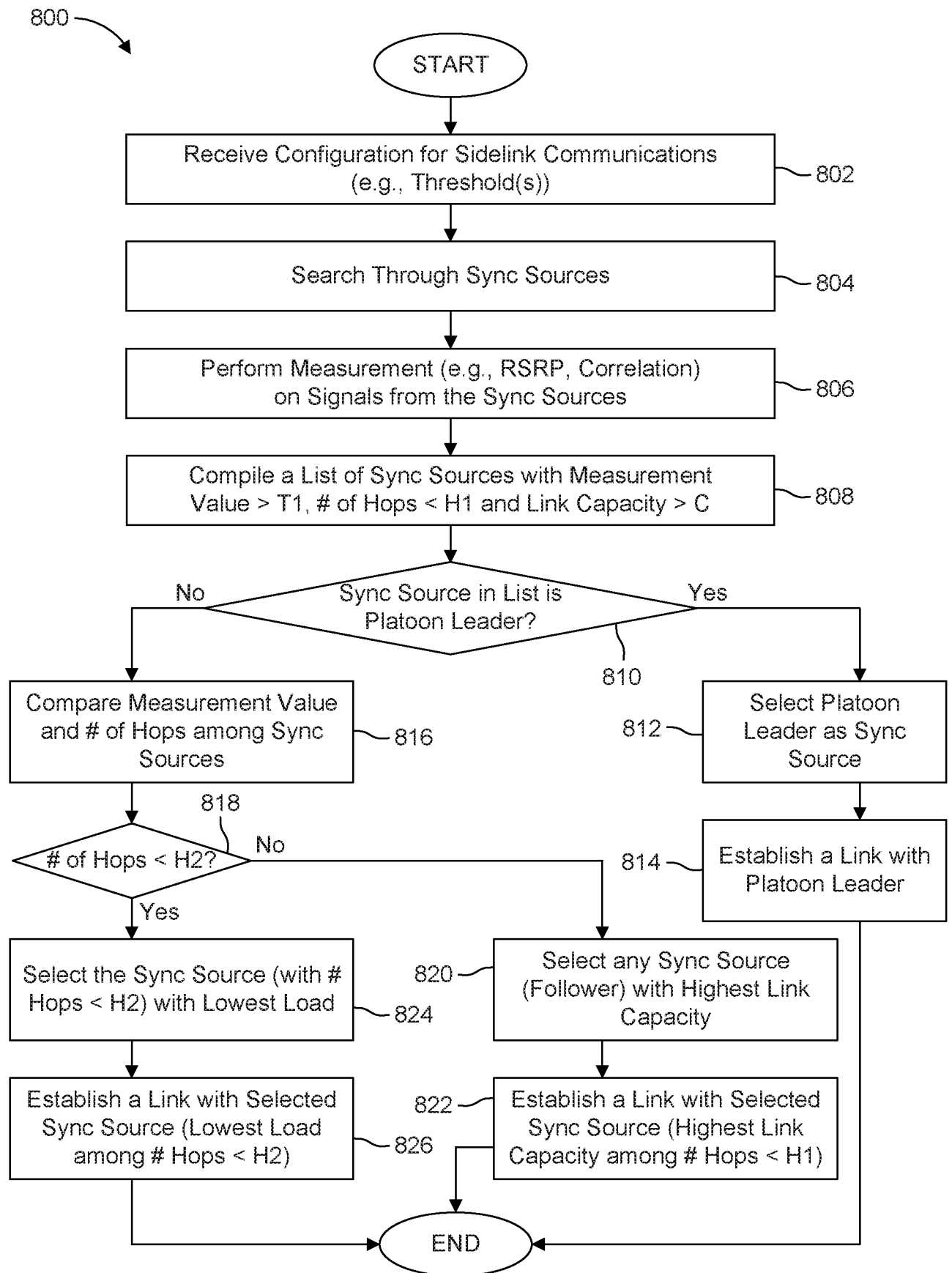


FIG. 8

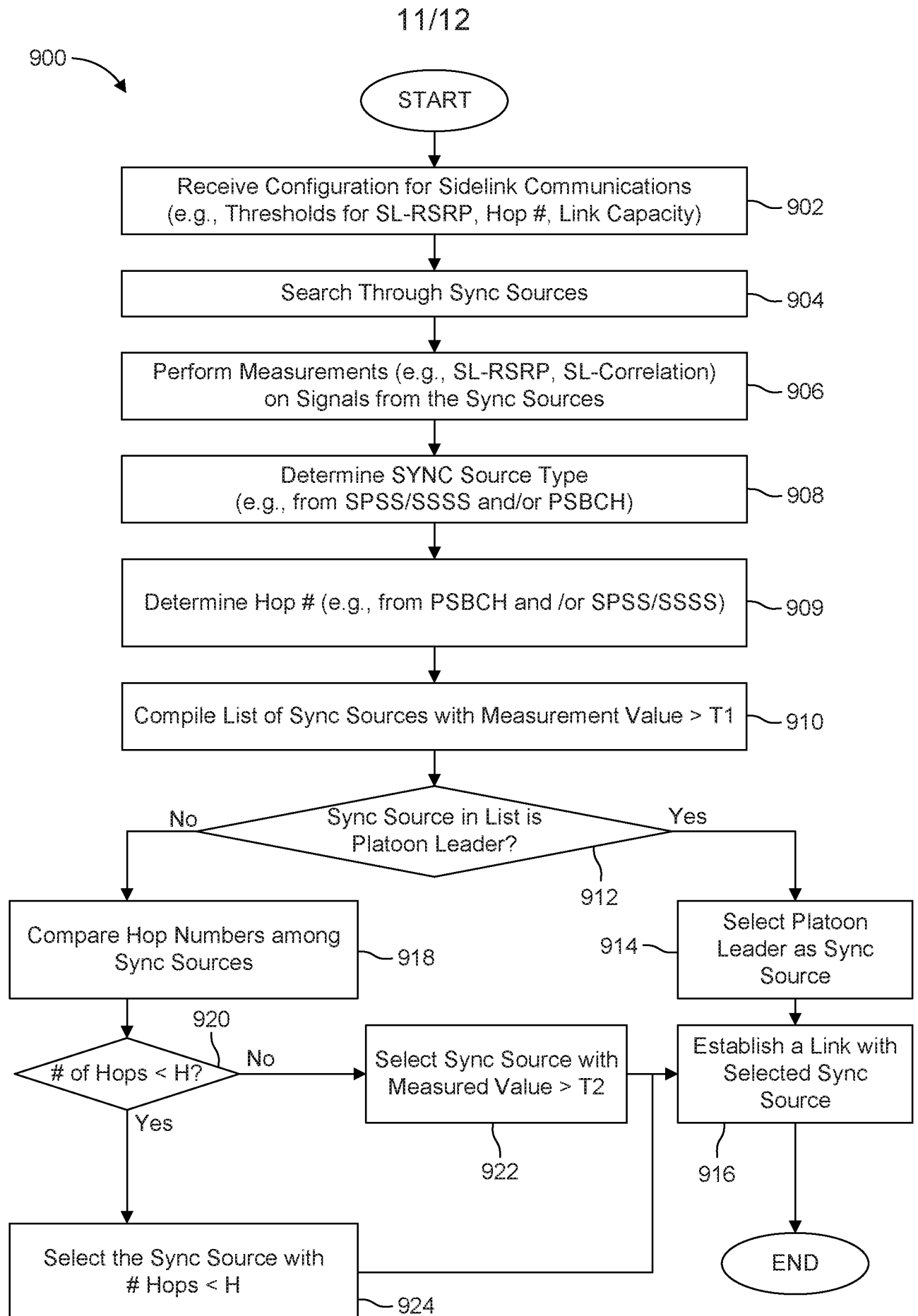


FIG. 9

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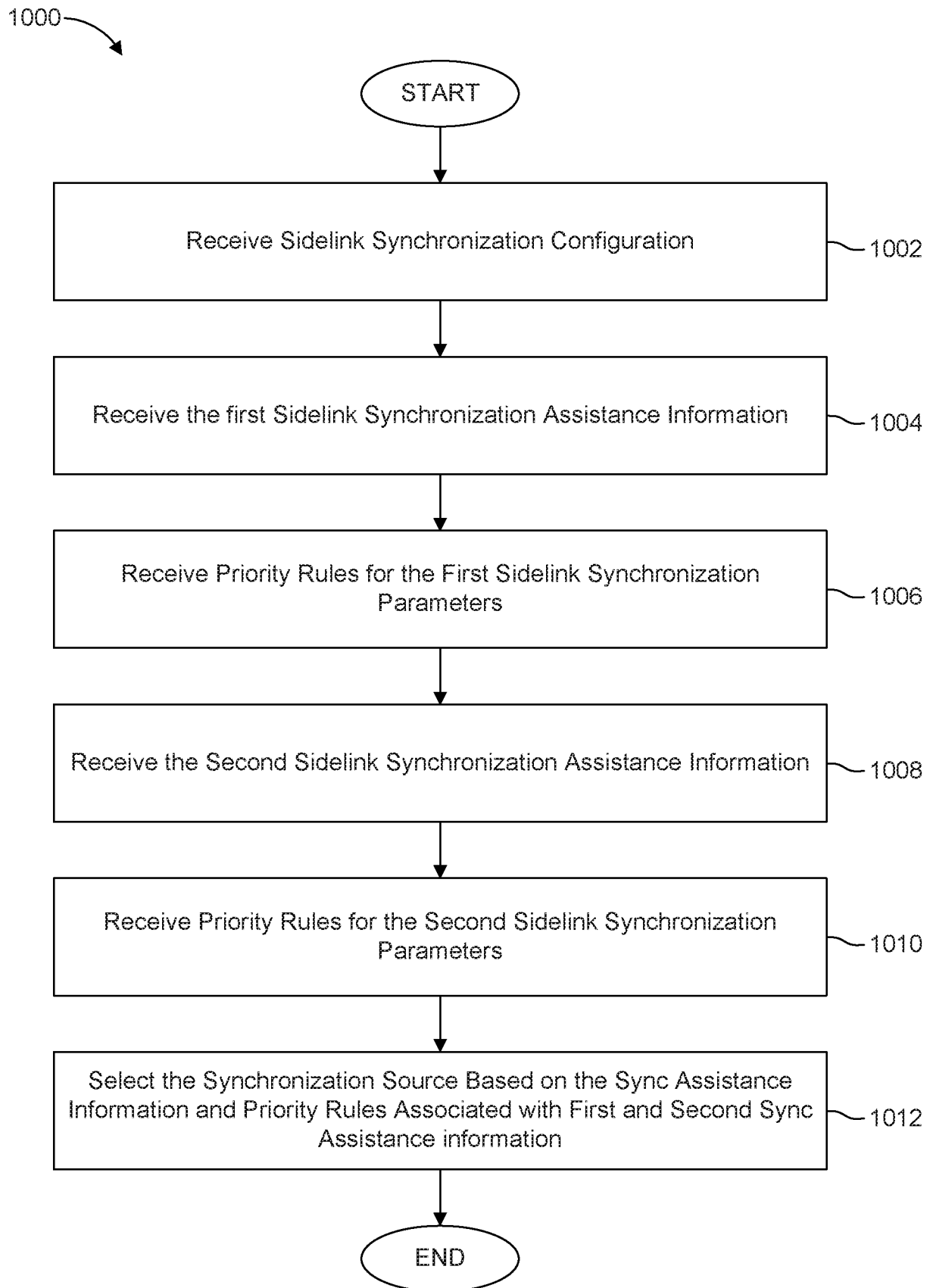


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/053238

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W56/00
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/331620 A1 (TSAI HUA-LUNG [TW] ET AL) 16 November 2017 (2017-11-16) paragraph [0027] paragraph [0022] paragraph [0017] paragraph [0020] paragraph [0006] paragraph [0032] paragraph [0026] ----- -/--	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

24 October 2019

Date of mailing of the international search report

31/10/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Tavakol, Vahid

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/053238

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (Release 15)", 3GPP STANDARD; TECHNICAL SPECIFICATION; 3GPP TS 36.331, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG2, no. V15.2.2, 10 July 2018 (2018-07-10), pages 1-791, XP051474963, [retrieved on 2018-07-10] paragraph [5.10.8.2] -----	1-20
A	INTERDIGITAL INC: "On V2X Synchronization in NR", 3GPP DRAFT; R1-1809095, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Gothenburg, Sweden; 20180820 - 20180824 11 August 2018 (2018-08-11), XP051516464, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94/Docs/R1%2D1809095%2Ezip [retrieved on 2018-08-11] page 3, paragraph "4 SyncRef Selection" -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2019/053238

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2017331620 A1	16-11-2017	CN 107371233 A US 2017331620 A1	21-11-2017 16-11-2017
