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(54) Title: SYSTEM AND METHOD FOR SUPPORTING SYNCHRONIZATION IN SIDELINK COMMUNICATIONS

(57) Abstract: A method for providing synchronization information includes acquiring a first synchronization information from a synchronization source, and transmitting a second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

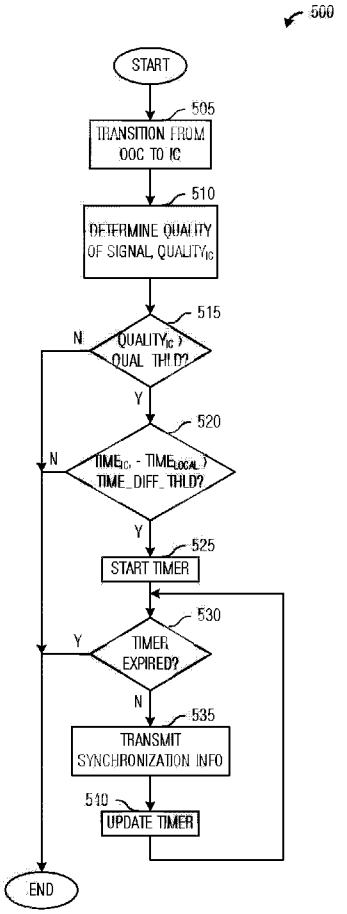


Fig. 5

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SYSTEM AND METHOD FOR SUPPORTING SYNCHRONIZATION IN SIDELINK COMMUNICATIONS

[1] This application claims priority to U.S. non-provisional patent application Serial No. 15/469,630, filed on March 27, 2017 entitled "System and Method for Supporting Synchronization in Sideline Communications," which in turn claims priority from U.S. Provisional patent application 62/316,277, filed on March 31, 2016, entitled "System and Method for Supporting Synchronization in Sideline Communications", both of which patent applications are incorporated herein by reference as if reproduced in their entireties.

TECHNICAL FIELD

[2] The present disclosure relates generally to a system and method for digital communications, and, in particular embodiments, to a system and method for supporting synchronization in sidelink communications.

BACKGROUND

[3] In general, two user equipments (UEs) that are synchronized to different timing sources will not be able to communicate with one another due to the timing difference between the timing sources. In vehicle to vehicle (V2V) communications, different timing sources, such as global navigation satellite system (GNSS) based timing, evolved NodeB (eNB) based timing, or local user equipment (UE) based timing, and so on, may be used. Specifically, an in-coverage (IC) UE, i.e., a UE that is operating within a coverage area of a GNSS or an eNB, and an out-of-coverage (OOC) UE, i.e., a UE that is not operating within the coverage area of a GNSS or an eNB, may have different timing which causes problems with UE communications that cross coverage edges or boundaries.

[4] Therefore, there is a need for a system and method for supporting synchronization in V2V communications. Hence, V2V communications can smoothly transition across system boundaries, e.g., between IC and OOC areas or areas with different timing sources.

SUMMARY

[5] Example embodiments provide a system and method for supporting synchronization in sidelink communications.

[6] In accordance with an example embodiment, a method for providing synchronization information is provided. The method includes acquiring, by a user equipment (UE), a first synchronization information from a synchronization source, and transmitting, by the UE, a

second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

[7] The second synchronization information is transmitted for a specified time period after the UE transitions from an out of coverage (OOC) UE to an in coverage (IC) UE. The UE is the IC UE when the UE determines that the synchronization source meets at least one criterion, and the UE is the OOC UE when the UE is unable to detect any synchronization source meeting the at least one criterion. The at least one criterion comprises measurements of signals from the synchronization source meeting a measurement threshold. The measurements comprise at least one of a carrier-to-noise ratio, a reference signal received power (RSRP), a reference signal received quality (RSRQ), or a reliability of the signals.

[8] The second synchronization information is transmitted until the UE is a specified distance away from a location where the UE transitions from the OOC UE to the IC UE. The second synchronization information is transmitted when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold. The second synchronization information is transmitted when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold and when a quality of signals from the synchronization source exceeds a quality threshold. The synchronization source includes at least one of a global navigation satellite system (GNSS), a GNSS-equivalent, an evolved NodeB (eNB), or a cell.

[9] The first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, and the second synchronization information is transmitted after the UE transitions to the OOC UE. The second synchronization information is transmitted for a specified time period after the UE transitions to the OOC UE. The synchronization source has an associated priority, and the second synchronization information is transmitted when the UE is unable to detect any other synchronization source with higher associated priority or a synchronization reference (SyncRef) UE. The second synchronization information is transmitted until the UE is a specified distance away from where the UE transitioned from the IC UE to the OOC UE.

[10] In accordance with an example embodiment, a method for providing synchronization information is provided. The method includes acquiring, by a UE, a first synchronization information from a synchronization source, and transmitting, by the UE, a second synchronization information derived from the first synchronization information, the second

synchronization information is transmitted when a quality of signals from the synchronization source meets a quality threshold.

[11] The quality of signals from the synchronization source is determined in accordance with at least one of a RSRP measurement, a carrier-to-noise ratio, a RSRQ measurement, and a reliability of the synchronization source.

[12] In accordance with an example embodiment, a UE is provided. The UE includes one or more processors, and a computer readable storage medium storing programming for execution by the one or more processors. The programming including instructions to configure the UE to acquire a first synchronization information from a synchronization source, and transmit a second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

[13] The programming includes instructions to configure the UE to transmit the second synchronization information for a specified time period after the UE transitions from an OOC UE to an IC UE. The programming includes instructions to configure the UE to transmit the second synchronization information until the UE is a specified distance away from a location where the UE transitions from the OOC UE to the IC UE. The programming includes instructions to configure the UE to transmit the second synchronization information when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold.

[14] The programming includes instructions to configure the UE to transmit the second synchronization information when a quality of signals from the synchronization source meets a quality threshold. The programming includes instructions to configure the UE to transmit the second synchronization information when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold and when a quality of signals from the synchronization source exceeds a quality threshold. The first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, the second synchronization information is transmitted after the UE transitions to the OOC UE, and the programming includes instructions to configure the UE to transmit the second synchronization information for a specified time period after the UE transitions to the OOC UE.

[15] The first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, the second synchronization information is transmitted after the UE transitions to the OOC UE, the synchronization source has an associated priority, and the

programming includes instructions to configure the UE to transmit the second synchronization information when the UE is unable detect any other synchronization source with higher associated priority or a synchronization reference (SyncRef) UE.

[16] Practice of the foregoing embodiments enables UEs to remain synchronized for a period of time or distance after crossing a service boundary. This enables UEs that are on different sides of the service boundary to remain in communications for a longer amount of time.

BRIEF DESCRIPTION OF THE DRAWINGS

[17] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[18] Figure 1 illustrates an example communications system according to example embodiments presented herein;

[19] Figure 2 illustrates an example communications system highlighting D2D synchronization according to example embodiments presented herein;

[20] Figure 3 illustrates an example communications system highlighting IC and OOC areas according to example embodiments presented herein;

[21] Figure 4 illustrates an example communications system highlighting a UE transitioning from OOC UE to IC UE according to example embodiments presented herein;

[22] Figure 5 illustrates a flow diagram of example operations occurring in a UE as the UE transitions from OOC UE to IC UE according to example embodiments presented herein;

[23] Figure 6 illustrates an example communications system highlighting a UE transitioning from IC UE to OOC UE according to example embodiments presented herein;

[24] Figure 7 illustrates a flow diagram of example operations occurring in a UE as the UE transitions from IC UE to OOC UE according to example embodiments presented herein;

[25] Figure 8 illustrates a block diagram of an embodiment processing system for performing methods described herein; and

[26] Figure 9 illustrates a block diagram of a transceiver adapted to transmit and receive signaling over a telecommunications network according to example embodiments presented herein.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[27] The making and using of the presently example embodiments are discussed in detail below. It should be appreciated, however, that the present disclosure provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the embodiments, and do not limit the scope of the disclosure.

[28] Figure 1 illustrates an example communications system 100. Communications system 100 includes a terrestrial communications network including an evolved NodeB (eNB) 105 and associated coverage area 107 and a global navigation satellite system (GNSS) 110, e.g., a global positioning system (GPS), and associated coverage area 112. Communications system 100 includes a plurality of user equipments (UEs), such as UE 115, UE 117, UE 119, and UE 121. Some of the UEs may communicate with one communications network, such as UE 115 and eNB 105 and UE 119 and GNSS 110, while some UEs may communicate with both communications network, such as UE 117 with eNB 105 and GNSS 110. Some UEs may not communicate with either communications network, such as UE 121. UEs, as used herein, may represent typical hand-held communications device, as well as communications devices that are part of a vehicle, such as a car, bus, or train, or communications devices of users riding in or on a vehicle. Furthermore, the UEs may also be roadside units (RSUs).

[29] While it is understood that communications systems may employ multiple eNBs and GNSSs capable of communicating with a number of UEs, only one eNB, one GNSS, and a number of UEs are illustrated for simplicity.

[30] In the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) Release-12 and Release-13 technical standards, device to device (D2D) synchronization techniques were presented. It is noted that V2V communications may be thought of as a further enhancement of D2D communications. In 3GPP LTE Release-12/13, IC UEs synchronized with eNBs and OOC UEs used sidelink synchronization information to synchronize with one another. The sidelink synchronization information includes a Sidelink Synchronization Signal (SLSS), timing information, as well as some additional configuration parameters (i.e., the MasterInformationBlock-SL (MIB-SL) message) and so on.

[31] In 3GPP Technical Standards TS 36.331, Section 5.10.7.2, which is hereby incorporated herein by reference, UEs may deliver eNB timing information to OOC UEs in certain scenarios. Figure 2 illustrates an example communications system 200 highlighting D2D synchronization. Communications system 200 includes an eNB 205 with coverage area 207.

Operating within coverage area 207, and therefore, is an IC UE, is UE 210. According to 3GPP TS 36.331, Section 5.10.7.2, an UE (such as UE 210) will transmit synchronization information with eNB timing when a reference signal received power (RSRP) of eNB 205 falls below a threshold, i.e., UE 210 is a cell edge UE (CEU).

[32] Also shown in Figure 2, are UEs 212, 214, and 216. These UEs are outside of coverage area 207 and in OOC 220, therefore, they may be referred to as OOC UEs. The OOC UEs may select a synchronization reference (SyncRef) UE according to priority rules as specified in the technical standards. As an illustrative example, UE 212 selects a SyncRef UE with eNB timing ("SLSS 1") with higher priority, while UE 214 cannot receive from SyncRef UE with eNB timing ("SLSS 1") and selects a SyncRef UE with hopped eNB timing ("SLSS 2") with higher priority. The priority may be indicated by an "inCoverage" field in the MIB-SL and an identifier of an SLSS (SLSSID), per 3GPP TS 36.331, Section 5.10.8.2).

[33] In D2D, cell edge UEs deliver the eNB timing to the OOC area so that UEs that are in coverage (i.e., IC UEs) enable communications with proximal UEs that are out of coverage (i.e., OOC UEs). In 3GPP PC5-based vehicle to everything (V2X) deployments, GNSS is introduced as an important synchronization source. UEs can use GNSS-based synchronization. Agreements on synchronization for PC5-based V2V in a V2X study item (SI):

- GNSS or GNSS-equivalent at the highest priority of synchronization source for time and frequency when the vehicle UE directly receives GNSS or GNSS-equivalent with sufficient reliability and the UE does not detect any cell in any carrier. GNSS-equivalent includes synchronization signals sent by GNSS synced eNBs;

- eNB instructs vehicle UE to prioritize either eNB-based synchronization or GNSS or GNSS-equivalent at least when the eNB is in the carrier where the vehicle UE operates on PC5 V2V.

[34] Figure 3 illustrates an example communications system 300 highlighting IC and OOC areas. Communications system 300 may be a GNSS that is supported by one or more satellites, such as satellite 305, or GNSS-equivalent devices. Within the coverage area of the one or more satellites is a tunnel 310. Because the signals of the one or more satellites are unlikely to penetrate tunnel 310, there is an OOC area in tunnel 310. While outside of tunnel 310 and in the coverage area of the one or more satellites (e.g., IC area 315 and IC area 317), UEs may be able to receive timing information from communications system 300 and are classified as IC UEs. However, the UEs that are inside tunnel 310 (e.g., OOC area 320), the UEs may not be able to receive timing information from communications system 300 and are classified as OOC UEs. IC

UEs and OOC UEs, as well as IC areas and OOC areas, may be defined based on availability or lack of GNSS or GNSS-equivalent signals. If the UE detects the GNSS or GNSS-equivalent signals from a synchronization source meeting one or more criterion, it shall consider itself to be IC. If the UE cannot detect any GNSS or GNSS-equivalent signals from any synchronization source meeting one or more criterion, it shall consider itself to be OOC. The one or more criterion can be based on the measurement of signals from synchronization source, such as carrier-to-noise ratio, RSRP, reference signal received quality (RSRQ), or reliability of the signal, or a combination thereof. An IC UE may also be expressed as a UE having GNSS or GNSS-equivalent, or a UE is synced with GNSS or GNSS-equivalent. An OOC UE may also be expressed as a UE without GNSS or GNSS-equivalent, or a UE is not synced with GNSS or GNSS-equivalent.

[35] As an alternative to GNSS or GNSS-equivalent synchronization sources, IC UEs and OOC UEs, as well as IC areas and OOC areas, may be defined based on the availability of eNB or cell signals or the lack thereof. In such a situation, if a UE detects that one or more signals from at least one eNB or cell on a frequency in which the UE is configured to perform sidelink operations meets one or more criterion, the UE considers itself to be IC and an IC UE. Conversely, if the UE fails to detect any signal that meets the one or more criterion, the UE considers itself to be OOC and an OOC UE. The one or more criterion can be based on the measurement of signals from synchronization source, such as carrier-to-noise ratio, RSRP, RSRQ, or reliability of the signal, or a combination thereof.

[36] When a UE is OOC, the UE will select a SyncRef UE (if there is any), and the SyncRef UE will transmit synchronization information periodically. The synchronization information may include a Sidelink Synchronization Signal (SLSS), timing information and some additional configuration parameters (i.e., the MasterInformationBlock-SL (MIB-SL) message), and so on, in 3GPP LTE V2V communications systems. However, V2V timing may be different for IC UEs and OOC UEs. The timing difference would make it impossible for the UEs to communicate across the IC/OOC or OOC/IC boundary. A boundary (e.g., an IC/OOC boundary or an OOC/IC boundary) may be defined as a location where an IC UE is no longer able to detect GNSS or GNSS-equivalent signals from a synchronization source meeting the one or more criterion (IC/OOC boundary) or a location where an OOC UE is able to detect GNSS or GNSS-equivalent signals from any synchronization source meeting the one or more criterion (OOC/IC boundary). Referring back to Figure 3, boundary 322 exists between IC 315 and OOC 320 and boundary 324 exists between OOC 320 and IC 317. Boundary 322 would make it impossible for UE 330 to communicate with UE 332, while boundary 324 would make it impossible for UE 334 to

communicate with UE 336. It is noted that although boundaries 322 and 324 are shown as coinciding with the start and the send of tunnel 310, actual boundaries depend on environmental conditions and may change over time. As an example, heavy clouds or rain can weaken a GNSS signal and cause boundaries to shift, enlarging OOC 320. As another example, the growth of shrubbery or trees about the openings of tunnel 310 may attenuate the GNSS signal and cause boundaries to shift, enlarging OOC 320. As yet another example, an eNB is added at the openings of tunnel 310 and the eNB transmits GNSS-equivalent signals into tunnel 310, the boundaries may shift, shrinking OOC 320.

[37] Simply reusing the D2D techniques proposed in 3GPP technical standards TS 36.331 may not work, since UEs with GNSS timing transmit synchronization information when the RSRP of the GNSS signal is below a specified threshold. This situation is similar to what occurs with cell edge UEs. There is small probability that the above situation is triggered. In some cases, such as in a tunnel or an underground parking structure, there may be a jump in the RSRP at a GNSS coverage edge, and in general, UEs move rapidly across a coverage edge boundary. Hence, a UE has very little time to transmit synchronization information with the GNSS timing information before it becomes OOC UE. However, a UE usually needs several SLSSs to obtain synchronization. It is therefore very likely that UEs out of GNSS coverage (OOC UEs) cannot synchronize to the UE transmitting the synchronization information with the GNSS timing before the UE loses the GNSS or GNSS-equivalent signal and becomes an OOC UE itself. Hence, the SLSS transmission discussion previously presented may not be effective in forwarding the synchronization information with the GNSS timing in PC5-based V2V.

[38] According to an example embodiment, a system and method that provides synchronization information to align V2V timing of IC UEs and OOC UEs are presented. The OOC UEs which receive the synchronization information can maintain communication with proximal IC UEs.

[39] According to an example embodiment, an UE transmits synchronization information (with GNSS timing information or GNSS-equivalent timing information transmitted by an eNB or a cell, or timing information transmitted by an eNB or a cell in a frequency configured for sidelink operation for the UE, for example) for a specified time T after the UE changes from OOC UE to IC UE. The UE may transmit the synchronization information for the specified time T after the UE changes from OOC UE to IC UE if the UE does not detect any other higher priority synchronization source or SyncRef UE. Alternatively, the UE may transmit the

synchronization information for the specified time T after the UE changes from OOC UE to IC UE if the UE does not detect any other synchronization source or SyncRef UE.

[40] As the UE acquires the synchronization information, which may occur before or after the UE transitions into the IC area, the UE will transmit the synchronization information (or a modified version thereof that is derived from the acquired synchronization information received from the GNSS or GNSS-equivalent, eNB, cell, or E-UTRAN) for the specified time T. The modifications to the synchronization information may include changes to or the addition of the timing information, configuration parameters, identifiers for transmission, and so on. As an illustrative example, until specified time T has elapsed from when the UE is IC or the UE has acquired the synchronization information, the UE remains sufficiently close to the OOC area so that the synchronization information transmitted by the UE will propagate sufficiently far into the OOC area to assist the OOC UEs. The OOC UEs that receive the synchronization information can also transmit the synchronization information or adjusted synchronization information (derived from the synchronization information received from the UE, for example) further. The specified time T may be defined relative to when the UE acquires the synchronization information or when the UE changes from OOC to IC. The specified time T may be specified in a technical standard, by an operator of the communications system, configured by the network, eNB, cell, or E-UTRAN, or preconfigured.

[41] As an alternative, instead of the specified time T, the UE will transmit the synchronization information for a specified distance D from where the UE acquired the synchronization information or from where the UE transitions from OOC to IC. As an illustrative example, as long as the UE remains within the specified distance D from where the UE acquired the synchronization information or from where the UE transitions from OOC to IC, its transmissions of the synchronization information or a modified version thereof may be able to propagate sufficiently far into the OOC area to assist OOC UEs. The OOC UEs that receive the synchronization information can also propagate the synchronization information or adjusted synchronization information (derived from the synchronization information received from the UE, for example) further. The specified distance D may be specified in a technical standard, by an operator of the communications system, configured by the network, eNB, cell, or E-UTRAN, or preconfigured.

[42] Figure 4 illustrates an example communications system 400 highlighting a UE transitioning from OOC to IC. Communications system 400 may be a GNSS that is supported by one or more satellites, such as satellite 405, or GNSS-equivalent devices, such as an eNB or cell.

It is noted that although the description presented herein focuses on GNSS or GNSS-equivalents, the example embodiments presented herein are also operable with systems where synchronization signals are based on signals transmitted by eNBs, cells, E-UTRANs, and so forth. Therefore, the discussion of GNSS or GNSS-equivalents should not be construed as being limiting to either the scope or spirit of the example embodiments. Within the coverage area of the one or more satellites is a tunnel 410. As a result of tunnel 410, there is a break in the coverage of the one or more satellites, resulting in an IC area 415, an OOC area 420, and an IC area 417. A UE 425 traversing tunnel 410 may cross boundary 430, which may be defined as where UE 425, which is an OOC UE in tunnel 410, becomes able to detect GNSS or GNSS-equivalent signals from any synchronization source meeting one or more criterion. Boundary 430 may or may not coincide with the end of tunnel 410. When UE 425 crosses boundary 430 (now shown as UE 426 to reduce confusion), UE 426 transitions from OOC to IC. At time $TIME_{IC}$, UE 426 may acquire synchronization information (event 435). Although $TIME_{IC}$ is shown in Figure 4 as occurring after UE 426 crosses boundary 430, it may be possible that UE 426 is able to acquire the synchronization information prior to crossing boundary 430. Once UE 426 acquires the synchronization information, UE 426 will transmit the synchronization information or a modified version thereof for a specified time T (until $TIME_{IC}$ + T, for example). The transmission of the synchronization information by UE 426 propagates back into OOC area 420 to provide OOC UEs with the synchronization information, which will help the OOC UEs to communicate with IC UEs. As discussed previously, instead of transmitting the synchronization information for the specified time T, UE 426 will transmit the synchronization information for the specified distance D. It is noted that in some situations, the time $TIME_{IC}$ can also be the time UE 426 transitions from OOC to IC.

[43] According to an example embodiment, a signal quality threshold or a signal quality criterion is used to determine if the UE will transmit the synchronization information. As an illustrative example, the UE will transmit the synchronization information only if the RSRP measurement, a RSRQ measurement, a carrier-to-noise ratio, a reliability of the synchronization is higher than a specified signal quality threshold or a signal quality criterion is fulfilled. The use of the specified signal quality threshold or criterion helps to prevent a situation where the UE transmits the synchronization information when the synchronization information/signals quality is poor.

[44] According to an example embodiment, a timing difference threshold or a timing difference criterion is used to determine if the UE will transmit the synchronization information. As an illustrative example, the UE will compare the synchronization information acquired with

its own local synchronization information and the UE will transmit the synchronization information only if the difference between the synchronization information acquired and its own local synchronization information is greater than a specified timing difference threshold. If the difference is less than the specified timing difference threshold, the local synchronization information of the UE (and the local synchronization information of the OOC UEs in the OOC area that the UE has just left) is within tolerable range and communications across the boundary can take place, therefore, the UE does not have to transmit the synchronization information. If the difference is greater than the specified timing difference threshold, then the local synchronization information of the UE (as well as the local synchronization information of the OOC UEs in the OOC area) is outside of the tolerable range and communications across the boundary cannot take place, therefore, the UE should transmit the synchronization information or a modified version thereof.

[45] Figure 5 illustrates a flow diagram of example operations 500 occurring in a UE as the UE transitions from OOC to IC. Operations 500 may be indicative of operations occurring in a UE as the UE transitions from OOC to IC. In other words, the UE experienced a coverage change from OOC to IC.

[46] Operations 500 begin with the UE transitioning from OOC to IC (block 505). Part of the transition from OOC to IC involves the UE receiving synchronization information that may be transmitted by a satellite of a GNSS, an eNB that is synced to a GNSS, and so on. It is noted that although the description presented herein focuses on GNSS or GNSS-equivalents, the example embodiments presented herein are also operable with systems where synchronization signals are based on signals transmitted by eNBs, cells, E-UTRANs, and so forth. Therefore, the discussion of GNSS or GNSS-equivalents should not be construed as being limiting to either the scope or spirit of the example embodiments. Alternatively, the synchronization signal may be transmitted by an eNB that is not using GNSS timing. In such a situation, the eNB may provide a timing difference between the synchronization signals and the GNSS timing. The UE determines a quality of the signal carrying the synchronization information, $QUALITY_{IC}$ (block 510). As an example, the UE determines a RSRP or RSRQ of the signal. The UE compares the quality of the signal with a signal quality threshold or signal quality criterion (block 515). As an illustrative example, an RSRP quality threshold may be set at around -120 dBm, -110 dBm, -100 dBm, etc., while an RSRQ threshold may be set at -20 dB, -19 dB, -18 dB, -17 dB, and so on. The actual values of the thresholds may be specified by a technical standard, an operator of the communications system, the network, a collaboration between the UEs and the network, and so on. If the quality of the signal does not exceed the signal quality threshold, operations 500 may

end. Alternatively, the UE may return to block 510 to wait until the quality of the signal to improve. The quality of the signal may improve as the UE moves about.

[47] If the quality of the signal is better than the signal quality threshold, the UE performs a check to determine if a difference between the synchronization information acquired and its local synchronization information is greater than a timing difference threshold or timing difference criterion (block 520). As an illustrative example, the timing difference is set as a fraction of the cyclic prefix, such as 1/2, 1/3, 1/4, etc., of the cyclic prefix. The actual value of the timing difference threshold may be specified by a technical standard, an operator of the communications system, the network, a collaboration between the UEs and the network, and so on. With this check, the UE may be checking to see if its local synchronization information is within acceptable tolerance of the synchronization information acquired. If the difference is less than the timing difference threshold, the UE does not transmit the synchronization information since the local synchronization information is within acceptable tolerance levels and due to the sharing of the local synchronization information, the OOC UEs in the OOC area share approximately the same local synchronization information. If the difference is greater than the timing difference threshold, the UE starts a timer (block 525). The timer may be an implementation of the UE transmitting the synchronization information for the specified time T after it transitions from OOC to IC or after it acquires the synchronization information or after it determines that the timing difference is greater than the timing difference threshold. The timer may be preconfigured to count from the specified time T down to 0, for example. As an illustrative example, the timer may be set to a number of radio frames, such as 10, 20, 30, and so on, frames or seconds, such as 10, 20, 30, or so milliseconds. The timer may be set back on the velocity of the UE, for example. The actual value of the timer may be specified by a technical standard, an operator of the communications system, the network, a collaboration between the UEs and the network, and so on. The UE performs a check to determine if the timer has expired (block 530). When the timer expires, it has been the specified time T since the UE transitioned from OOC to IC or after it acquires the synchronization information or after it determines that the timing difference is greater than the timing difference threshold.

[48] If the timer has not expired, the UE transmits the synchronization information or a modified version thereof since the local synchronization information is not within acceptable tolerance levels (block 535). The UE updates the timer (block 540) and returns to block 530 to check if the timer has expired.

[49] As an alternative, the UE may simply transmit the synchronization information or a modified version thereof for a specified time T without checking to determine if the signal quality meets the signal quality threshold. As another alternative, the UE may simply transmit the synchronization information or a modified version thereof for a specified time T without checking to determine if the local synchronization information is within tolerance of the synchronization information acquired. As yet another alternative, the UE may simply transmit the synchronization information or a modified version thereof for a specified time T without checking to determine if the signal quality meets the signal quality threshold and checking to determine if the local synchronization information is within tolerance of the synchronization information.

[50] Alternatively, the UE uses a distance based metric to determine if it should transmit or continue to transmit the synchronization information or a modified version thereof. In such a situation, the timer may be replaced with a numerical value check that is based on a measured distance between the UE and a location where the UE transitioned from OOC to IC or where it acquires the synchronization information or where it determines that the timing difference is greater than the timing difference threshold. As an illustrative example, the distance may be set based on how quickly the UE is moving, and may be set as a function of how far the UE is expected to travel in the amount of time T set to the timer (discussed above). Examples of the distance may include 20, 30, 40, and so forth, meters. The actual value of the distance may be specified by a technical standard, an operator of the communications system, the network, a collaboration between the UEs and the network, and so on. As an example, GNSS position information or location information maintained by the UE may be used to generate the numerical value.

[51] According to RAN4 assumptions for D2D operation and related analysis in 3GPP V2X, it takes about 2 minutes for GNSS timing to drift out of the normal cyclic prefix (CP). Therefore, synchronization may be maintained in the UE for several minutes after GNSS is lost.

[52] According to an example embodiment, a UE transmits synchronization information (with GNSS timing information, for example) for a specified time T after the UE transitions from IC to OOC. After the UE transitions into OOC, the UE continues to transmit the synchronization information or a modified version thereof for the specified time T. Alternatively, after the UE transitions into OOC, if the UE doesn't detect any other higher priority synchronization source or SyncRef UE meeting a criterion, the UE continues to transmit the synchronization information or a modified version thereof for the specified time T. As an

illustrative example, until specified time T has elapsed from when the UE transitioned into OOC, the UE transmits the synchronization information or a modified version thereof acquired prior to transitioning to OOC, with updates performed locally and based on local timing of the UE. The OOC UEs that receive the synchronization information can also propagate the synchronization information or adjusted synchronization information further. After the specified time T, the UE transmits synchronization information based on D2D rules. As an alternative, instead of the specified time T, the UE will transmit the synchronization information or a modified version thereof for a specified distance D from where the UE transitioned to OOC. After the distance D, the UE transmits synchronization information based on D2D rules.

[53] Figure 6 illustrates an example communications system 600 highlighting a UE transitioning from IC to OOC. Communications system 600 may be a GNSS that is supported by one or more satellites, such as satellite 605, or GNSS-equivalent devices, such as an eNB or cell. It is noted that although the description presented herein focuses on GNSS or GNSS-equivalents, the example embodiments presented herein are also operable with systems where synchronization signals are based on signals transmitted by eNBs, cells, E-UTRANs, and so forth. Therefore, the discussion of GNSS or GNSS-equivalents should not be construed as being limiting to either the scope or spirit of the example embodiments. Within the coverage area of the one or more satellites is a tunnel 610. As a result of tunnel 610, there is a break in the coverage of the one or more satellites, resulting in an IC area 615, an OOC area 620, and an IC area 617. A UE 625 traversing towards tunnel 610 may cross boundary 630, which may be defined as where UE 625, which is an IC UE before tunnel 610, becomes unable to detect GNSS or GNSS-equivalent signals from any synchronization source meeting one or more criterion. Boundary 630 may or may not coincide with the end of tunnel 610. When UE 625 crosses boundary 630 (now shown as UE 626 to reduce confusion), UE 626 transitions from IC to OOC. At time $TIME_{OOC}$, UE 626 crosses boundary 630 and may lose IC timing (event 635). Once UE 626 loses IC timing, UE 626 will transmit the synchronization information (along with timing updates based on its own clock) or a modified version thereof for a specified time T (until $TIME_{OOC}$ + T, for example). As an illustrative example, the specified time T is related to characteristics of the crystal oscillator of the UE, such as the clock drift of the crystal oscillator. If the clock drift is high, the specified time T may be low, while if the clock drift is low, the specified time may be high. Example values of T may be on the order of tens of seconds to several minutes. The actual value of the time may be specified by a technical standard, an operator of the communications system, the network, a collaboration between the UEs and the network, and so on. As discussed previously, a UE that has recently lost IC timing may still

maintain local IC timing for a period of time. However, the local IC timing becomes more inaccurate with the passage of time. The transmission of the synchronization information (including IC timing) by UE 626 propagates forward into OOC area 620 to provide OOC UEs with the IC timing, which will help the OOC UEs to communicate with IC UEs. A UE that has just recently lost IC timing may be given more priority than a UE that has lost IC timing a significant time ago. Therefore, a priority based technique may be implemented to enable OOC UEs to determine which synchronization information to use to update its own local synchronization information. As an illustrative example, the UE may be prioritized based on time since loss of IC timing, with the most recent UEs being given the highest priority or weight. As discussed previously, instead of transmitting the synchronization information or a modified version thereof for the specified time T, UE 626 will transmit the synchronization information or a modified version thereof for the specified distance D.

[54] Figure 7 illustrates a flow diagram of example operations 700 occurring in a UE as the UE transitions from IC to OOC. Operations 700 may be indicative of operations occurring in a UE as the UE transitions from IC to OOC. In other words, the UE experienced a coverage change from IC to OOC.

[55] Operations 700 begin with the UE transitioning from IC to OOC (block 705). As a result of its transition from IC to OOC, the UE has stopped receiving synchronization information from the synchronization source. The UE performs a check to determine if it is able to detect a higher priority synchronization source or a SyncRef UE meeting a criterion (block 710). If the UE is able to detect a higher priority synchronization source or a SyncRef UE, operations 700 may terminate. If the UE is not able to detect a higher priority synchronization source or a SyncRef UE meeting a criterion, the UE performs a check to determine if the time since when it transitioned to OOC to a current time is less than a time threshold or a time criterion (block 715). As discussed previously, if the UE has loss IC timing for less than a certain amount of time, it is expected that the UE's local synchronization information will remain valid. If the time since when the UE transitioned to OOC to the current time is less than the time threshold, the UE transmits its local synchronization information, which may be an updated version of the synchronization information received from the synchronization source prior to transitioning to OOC (block 720) and the UE returns to block 715 to repeat the check. If the time since when the UE transitioned to OOC to the current time is more than the time threshold, operations 700 may terminate.

[56] As an alternatively, the check to determine if the local synchronization information remains within tolerance starts when the UE transitions to OOC. As another alternative, the check to determine if the local synchronization information remains within tolerance starts when the UE stops receiving the synchronization information. As yet another alternatively, the UE does not check to determine if there is a higher priority synchronization source or SyncRef UE prior to transmitting the local synchronization information.

[57] As aforementioned descriptions are focused on vehicle to vehicle communication, the similar procedures can also be applied to general device to device communications.

[58] In a first aspect, the present application provides a method for providing synchronization information is provided. The method includes acquiring, by a UE, a first synchronization information from a synchronization source, and transmitting, by the UE, a second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

[59] According to a first embodiment of the method according to the first aspect, the second synchronization information is transmitted for a specified time period after the UE transitions from an OOC UE to an IC UE. According to a second embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the UE is the IC UE when the UE determines that the synchronization source meets at least one criterion, and the UE is the OOC UE when the UE is unable to detect any synchronization source meeting the at least one criterion. According to a third embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the at least one criterion comprises measurements of signals from the synchronization source meeting a measurement threshold. According to a fourth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the measurements comprise at least one of a carrier-to-noise ratio, a reference signal received power (RSRP), a reference signal received quality (RSRQ), or a reliability of the signals.

[60] According to a fifth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the second synchronization information is transmitted until the UE is a specified distance away from a location where the UE transitions from the OOC UE to the IC UE. According to a sixth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the second synchronization information is transmitted when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference

threshold. According to a seventh embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the second synchronization information is transmitted when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold and when a quality of signals from the synchronization source exceeds a quality threshold. According to an eighth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the synchronization source includes at least one of a global navigation satellite system (GNSS), a GNSS-equivalent, an evolved NodeB (eNB), or a cell.

[61] According to a ninth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, and the second synchronization information is transmitted after the UE transitions to the OOC UE. According to a tenth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the second synchronization information is transmitted for a specified time period after the UE transitions to the OOC UE. According to an eleventh embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the synchronization source has an associated priority, and the second synchronization information is transmitted when the UE is unable to detect any other synchronization source with higher associated priority or a synchronization reference (SyncRef) UE. According to a twelfth embodiment of the method according to any preceding embodiment of the first aspect or the first aspect as such, the second synchronization information is transmitted until the UE is a specified distance away from where the UE transitioned from the IC UE to the OOC UE.

[62] In a second aspect, the present application provides a method for providing synchronization information. The method includes acquiring, by a UE, a first synchronization information from a synchronization source, and transmitting, by the UE, a second synchronization information derived from the first synchronization information, the second synchronization information is transmitted when a quality of signals from the synchronization source meets a quality threshold.

[63] According to a first embodiment of the method according to the second aspect, the quality of signals from the synchronization source is determined in accordance with at least one of a RSRP measurement, a carrier-to-noise ratio, a RSRQ measurement, and a reliability of the synchronization source.

[64] According to an example embodiment, a signal quality threshold or a signal quality criterion is used to determine if the UE will transmit the synchronization information. As an illustrative example, the UE will transmit the synchronization information only if at least one of the RSRP measurement, a RSRQ measurement, a carrier-to-noise ratio, a reliability of the synchronization source is higher than a specified signal quality threshold or a signal quality criterion is fulfilled. The synchronization source comprises one of a GNSS, a GNSS-equivalent, an eNB, and a cell.

[65] In a third aspect, the present application provides a UE. The UE includes one or more processors, and a computer readable storage medium storing programming for execution by the one or more processors. The programming including instructions to configure the UE to acquire a first synchronization information from a synchronization source, and transmit a second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

[66] According to a first embodiment of the UE according to the third aspect, the programming includes instructions to configure the UE to transmit the second synchronization information for a specified time period after the UE transitions from an OOC UE to an IC UE. According to a second embodiment of the UE according to any preceding embodiment of the third aspect or the third aspect as such, the programming includes instructions to configure the UE to transmit the second synchronization information until the UE is a specified distance away from a location where the UE transitions from the OOC UE to the IC UE. According to a third embodiment of the UE according to any preceding embodiment of the third aspect or the third aspect as such, he programming includes instructions to configure the UE to transmit the second synchronization information when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold.

[67] According to a fourth embodiment of the UE according to any preceding embodiment of the third aspect or the third aspect as such, the programming includes instructions to configure the UE to transmit the second synchronization information when a quality of signals from the synchronization source meets a quality threshold. According to a fifth embodiment of the UE according to any preceding embodiment of the third aspect or the third aspect as such, the programming includes instructions to configure the UE to transmit the second synchronization information when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference

threshold and when a quality of signals from the synchronization source exceeds a quality threshold. According to a sixth embodiment of the UE according to any preceding embodiment of the third aspect or the third aspect as such, the first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, the second synchronization information is transmitted after the UE transitions to the OOC UE, and the programming includes instructions to configure the UE to transmit the second synchronization information for a specified time period after the UE transitions to the OOC UE.

[68] According to a seventh embodiment of the UE according to any preceding embodiment of the third aspect or the third aspect as such, the first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, the second synchronization information is transmitted after the UE transitions to the OOC UE, the synchronization source has an associated priority, and the programming includes instructions to configure the UE to transmit the second synchronization information when the UE is unable detect any other synchronization source with higher associated priority or a synchronization reference (SyncRef) UE.

[69] Figure 8 illustrates a block diagram of an embodiment processing system 800 for performing methods described herein, which may be installed in a host device. As shown, the processing system 800 includes a processor 804, a memory 806, and interfaces 810-814, which may (or may not) be arranged as shown in Figure 8. The processor 804 may be any component or collection of components adapted to perform computations and/or other processing related tasks, and the memory 806 may be any component or collection of components adapted to store programming and/or instructions for execution by the processor 804. In an embodiment, the memory 806 includes a non-transitory computer readable medium. The interfaces 810, 812, 814 may be any component or collection of components that allow the processing system 800 to communicate with other devices/components and/or a user. For example, one or more of the interfaces 810, 812, 814 may be adapted to communicate data, control, or management messages from the processor 804 to applications installed on the host device and/or a remote device. As another example, one or more of the interfaces 810, 812, 814 may be adapted to allow a user or user device (e.g., personal computer (PC), etc.) to interact/communicate with the processing system 800. The processing system 800 may include additional components not depicted in Figure 8, such as long term storage (e.g., non-volatile memory, etc.).

[70] In some embodiments, the processing system 800 is included in a network device that is accessing, or part otherwise of, a telecommunications network. In one example, the processing system 800 is in a network-side device in a wireless or wireline telecommunications network, such as a base station, a relay station, a scheduler, a controller, a gateway, a router, an applications server, or any other device in the telecommunications network. In other embodiments, the processing system 800 is in a user-side device accessing a wireless or wireline telecommunications network, such as a mobile station, a user equipment (UE), a personal computer (PC), a tablet, a wearable communications device (e.g., a smartwatch, etc.), or any other device adapted to access a telecommunications network.

[71] In some embodiments, one or more of the interfaces 810, 812, 814 connects the processing system 800 to a transceiver adapted to transmit and receive signaling over the telecommunications network. Figure 9 illustrates a block diagram of a transceiver 900 adapted to transmit and receive signaling over a telecommunications network. The transceiver 900 may be installed in a host device. As shown, the transceiver 1000 comprises a network-side interface 902, a coupler 904, a transmitter 906, a receiver 908, a signal processor 910, and a device-side interface 912. The network-side interface 902 may include any component or collection of components adapted to transmit or receive signaling over a wireless or wireline telecommunications network. The coupler 904 may include any component or collection of components adapted to facilitate bi-directional communication over the network-side interface 902. The transmitter 906 may include any component or collection of components (e.g., up-converter, power amplifier, etc.) adapted to convert a baseband signal into a modulated carrier signal suitable for transmission over the network-side interface 902. The receiver 908 may include any component or collection of components (e.g., down-converter, low noise amplifier, etc.) adapted to convert a carrier signal received over the network-side interface 902 into a baseband signal. The signal processor 910 may include any component or collection of components adapted to convert a baseband signal into a data signal suitable for communication over the device-side interface(s) 912, or vice-versa. The device-side interface(s) 912 may include any component or collection of components adapted to communicate data-signals between the signal processor 910 and components within the host device (e.g., the processing system 800, local area network (LAN) ports, etc.).

[72] The transceiver 900 may transmit and receive signaling over any type of communications medium. In some embodiments, the transceiver 900 transmits and receives signaling over a wireless medium. For example, the transceiver 900 may be a wireless transceiver adapted to communicate in accordance with a wireless telecommunications protocol, such as a cellular protocol (e.g., long-term evolution (LTE), etc.), a wireless local area network (WLAN) protocol (e.g., Wi-Fi, etc.), or any other type of wireless protocol (e.g., Bluetooth, near field communication (NFC), etc.). In such embodiments, the network-side interface 902 comprises one or more antenna/radiating elements. For example, the network-side interface 902 may include a single antenna, multiple separate antennas, or a multi-antenna array configured for multi-layer communication, e.g., single input multiple output (SIMO), multiple input single output (MISO), multiple input multiple output (MIMO), etc. In other embodiments, the transceiver 900 transmits and receives signaling over a wireline medium, e.g., twisted-pair cable, coaxial cable, optical fiber, etc. Specific processing systems and/or transceivers may utilize all of the components shown, or only a subset of the components, and levels of integration may vary from device to device.

[73] It should be appreciated that one or more steps of the embodiment methods provided herein may be performed by corresponding units or modules. For example, a signal may be transmitted by a transmitting unit or a transmitting module. A signal may be received by a receiving unit or a receiving module. A signal may be processed by a processing unit or a processing module. Other steps may be performed by an acquiring unit/module. The respective units/modules may be hardware, software, or a combination thereof. For instance, one or more of the units/modules may be an integrated circuit, such as field programmable gate arrays (FPGAs) or application-specific integrated circuits (ASICs).

[74] Although the present disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method for providing synchronization information, the method comprising:

acquiring, by a user equipment (UE), a first synchronization information from a synchronization source; and

transmitting, by the UE, a second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

2. The method of claim 1, wherein the second synchronization information is transmitted for a specified time period after the UE transitions from an out of coverage (OOC) UE to an in coverage (IC) UE.

3. The method of claim 2, wherein the UE is the IC UE when the UE determines that the synchronization source meets at least one criterion, and wherein the UE is the OOC UE when the UE is unable to detect any synchronization source meeting the at least one criterion.

4. The method of claim 3, wherein the at least one criterion comprises measurements of signals from the synchronization source meeting a measurement threshold.

5. The method of claim 4, wherein the measurements comprise at least one of a carrier-to-noise ratio, a reference signal received power (RSRP), a reference signal received quality (RSRQ), or a reliability of the signals.

6. The method of claim 1, wherein the second synchronization information is transmitted until the UE is a specified distance away from a location where the UE transitions from the OOC UE to the IC UE.

7. The method of claim 1, wherein the second synchronization information is transmitted when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold.

8. The method of claim 1, wherein the second synchronization information is transmitted when a difference between the first synchronization information and local synchronization

information of the UE is greater than a timing difference threshold and when a quality of signals from the synchronization source exceeds a quality threshold.

9. The method of claim 1, wherein the synchronization source comprises at least one of a global navigation satellite system (GNSS), a GNSS-equivalent, an evolved NodeB (eNB), or a cell.

10. The method of claim 1, wherein the first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, and wherein the second synchronization information is transmitted after the UE transitions to the OOC UE.

11. The method of claim 10, wherein the second synchronization information is transmitted for a specified time period after the UE transitions to the OOC UE.

12. The method of claim 11, wherein the synchronization source has an associated priority, and wherein the second synchronization information is transmitted when the UE is unable to detect any other synchronization source with higher associated priority or a synchronization reference (SyncRef) UE.

13. The method of claim 10, wherein the second synchronization information is transmitted until the UE is a specified distance away from where the UE transitioned from the IC UE to the OOC UE.

14. A method for providing synchronization information, the method comprising:

acquiring, by a user equipment (UE), a first synchronization information from a synchronization source; and

transmitting, by the UE, a second synchronization information derived from the first synchronization information, wherein the second synchronization information is transmitted when a quality of signals from the synchronization source meets a quality threshold.

15. The method of claim 14, wherein the quality of signals from the synchronization source is determined in accordance with at least one of a reference signal received power (RSRP)

measurement, a carrier-to-noise ratio, a reference signal received quality (RSRQ) measurement, and a reliability of the synchronization source.

16. A user equipment (UE) comprising:

one or more processors; and

a computer readable storage medium storing programming for execution by the one or more processors, the programming including instructions to configure the UE to:

acquire a first synchronization information from a synchronization source, and

transmit a second synchronization information derived from the first synchronization information when the UE experiences a coverage change.

17. The UE of claim 16, wherein the programming includes instructions to configure the UE to transmit the second synchronization information for a specified time period after the UE transitions from an out of coverage (OOC) UE to an in coverage (IC) UE.

18. The UE of claim 16, wherein the programming includes instructions to configure the UE to transmit the second synchronization information until the UE is a specified distance away from a location where the UE transitions from the OOC UE to the IC UE.

19. The UE of claim 16, wherein the programming includes instructions to configure the UE to transmit the second synchronization information when a difference between the first synchronization information and local synchronization information of the UE is greater than a timing difference threshold.

20. The UE of claim 16, wherein the programming includes instructions to configure the UE to transmit the second synchronization information when a quality of signals from the synchronization source meets a quality threshold.

21. The UE of claim 16, wherein the programming includes instructions to configure the UE to transmit the second synchronization information when a difference between the first synchronization information and local synchronization information of the UE is greater than a

timing difference threshold and when a quality of signals from the synchronization source exceeds a quality threshold.

22. The UE of claim 16, wherein the first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, wherein the second synchronization information is transmitted after the UE transitions to the OOC UE, and wherein the programming includes instructions to configure the UE to transmit the second synchronization information for a specified time period after the UE transitions to the OOC UE.

23. The UE of claim 16, wherein the first synchronization information is acquired before the UE transitions from an IC UE to an OOC UE, and wherein the second synchronization information is transmitted after the UE transitions to the OOC UE, and wherein the synchronization source has an associated priority, and wherein the programming includes instructions to configure the UE to transmit the second synchronization information when the UE is unable detect any other synchronization source with higher associated priority or a synchronization reference (SyncRef) UE.

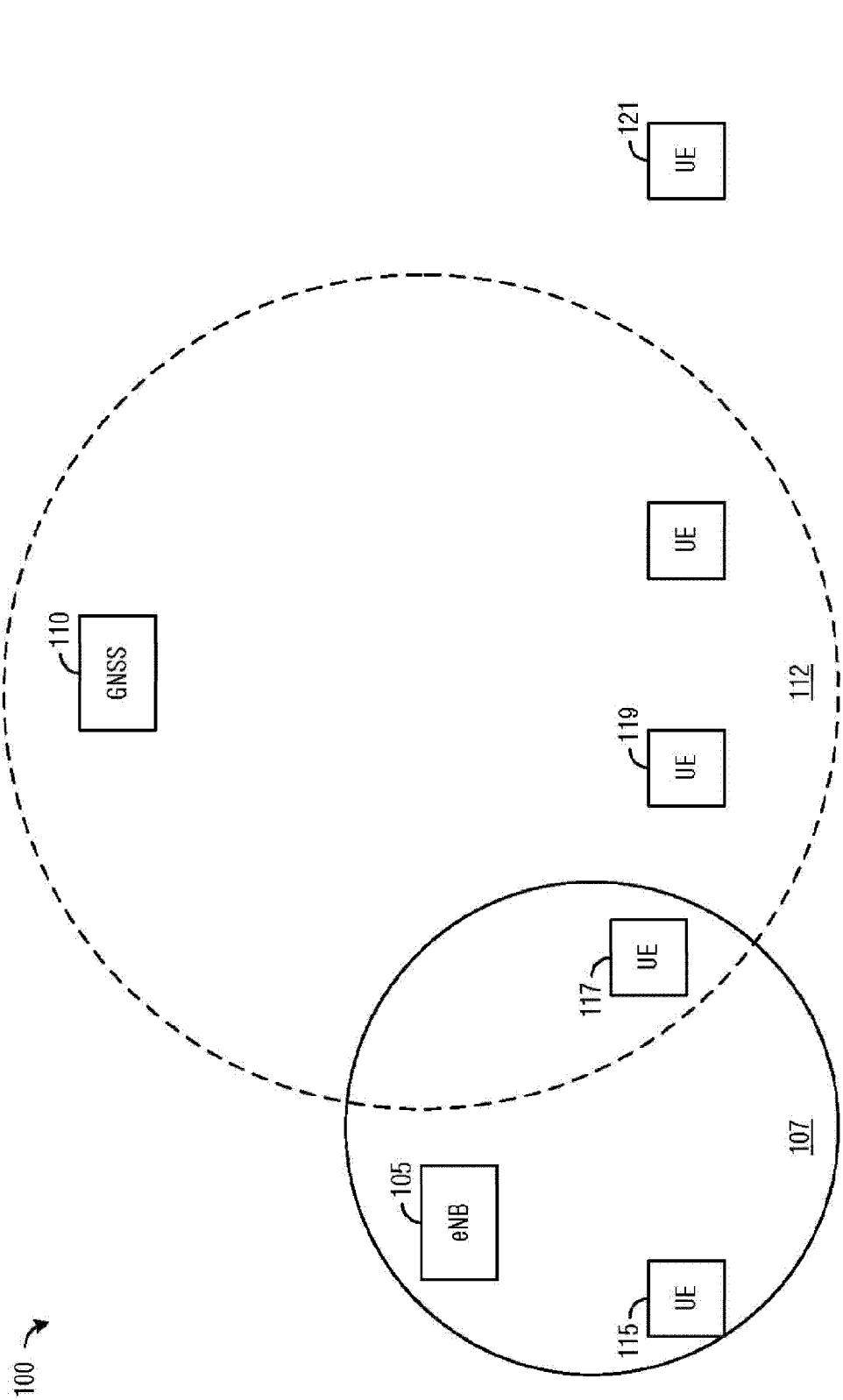


Fig. 1

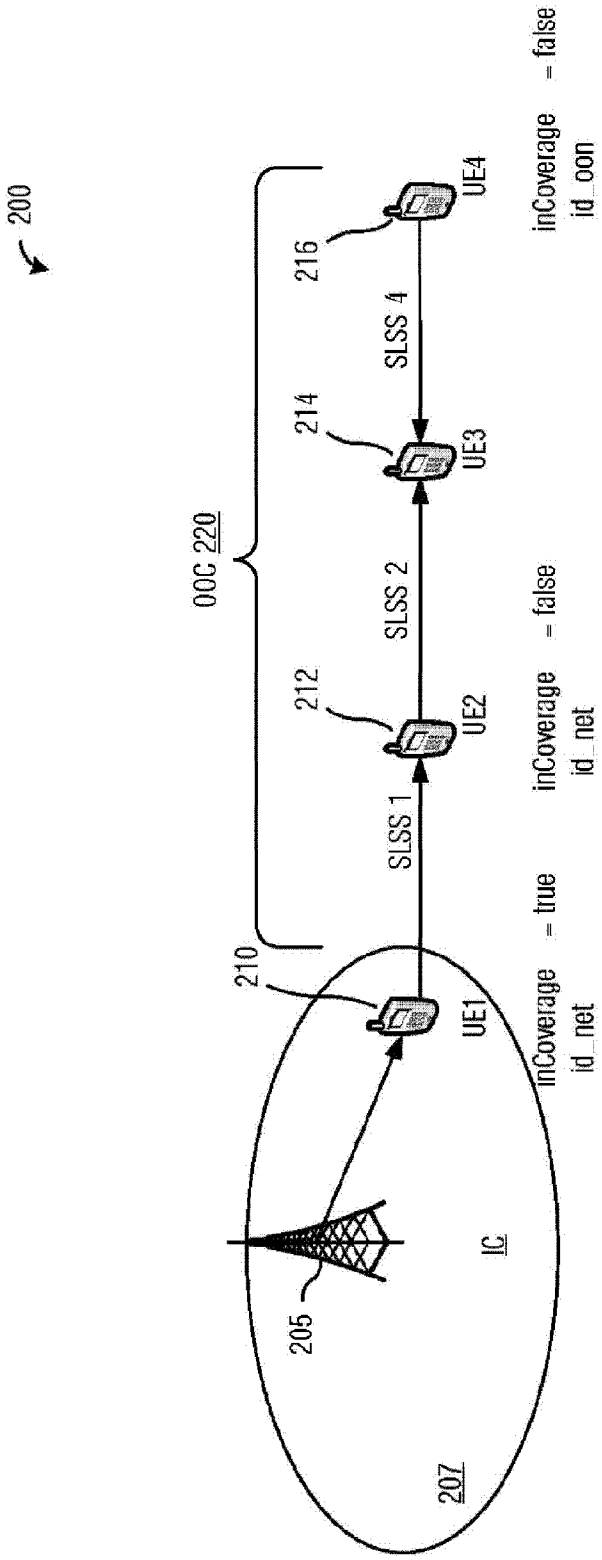

200
205
207
IC
210
UE1
inCoverage = true
id_net
SLSS 1
212
UE2
inCoverage = false
id_net
SLSS 2
214
UE3
SLSS 4
216
UE4
inCoverage = false
id_oon
OOC 220

Fig. 2

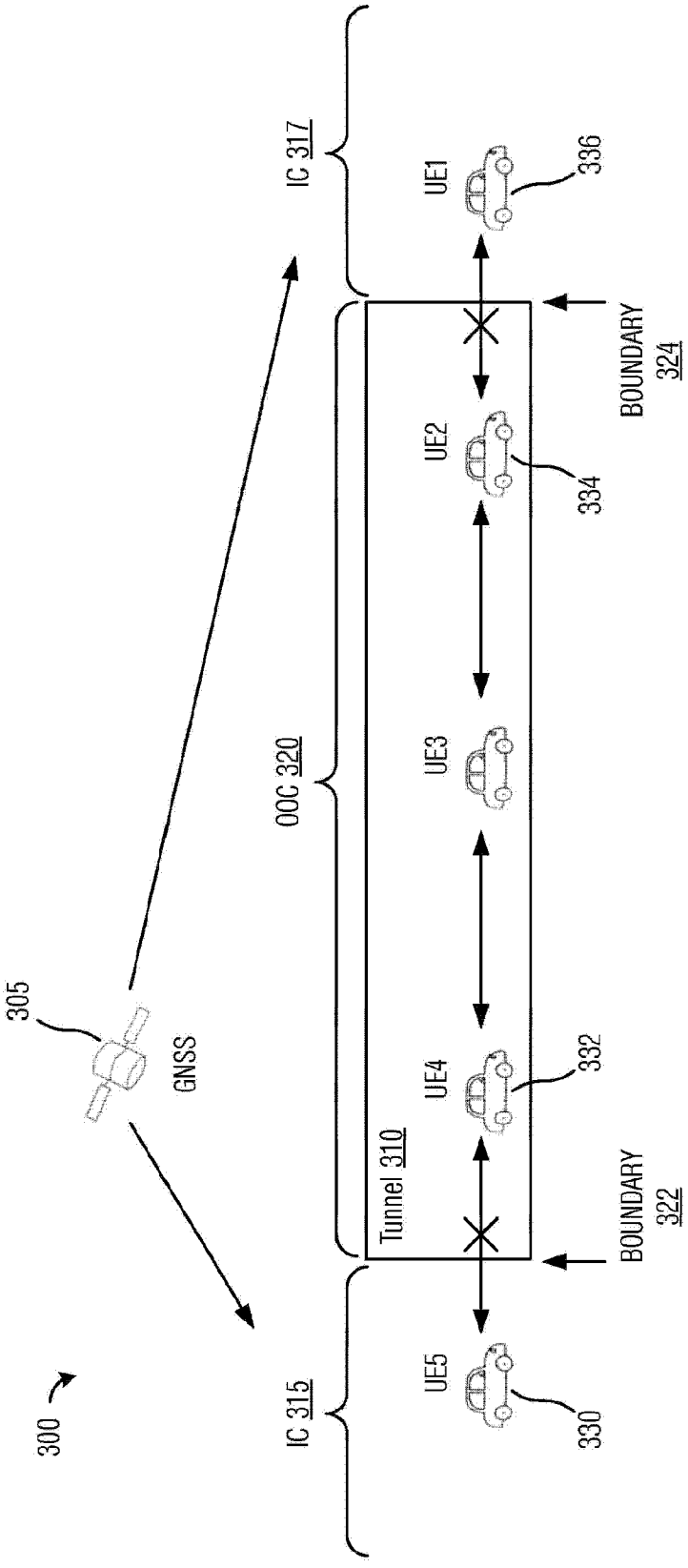

300
305
GNSS
IC 315
OOC 320
IC 317
Tunnel 310
BOUNDARY 322
BOUNDARY 324
UE1
UE2
UE3
UE4
UE5
330
332
334
336

Fig. 3

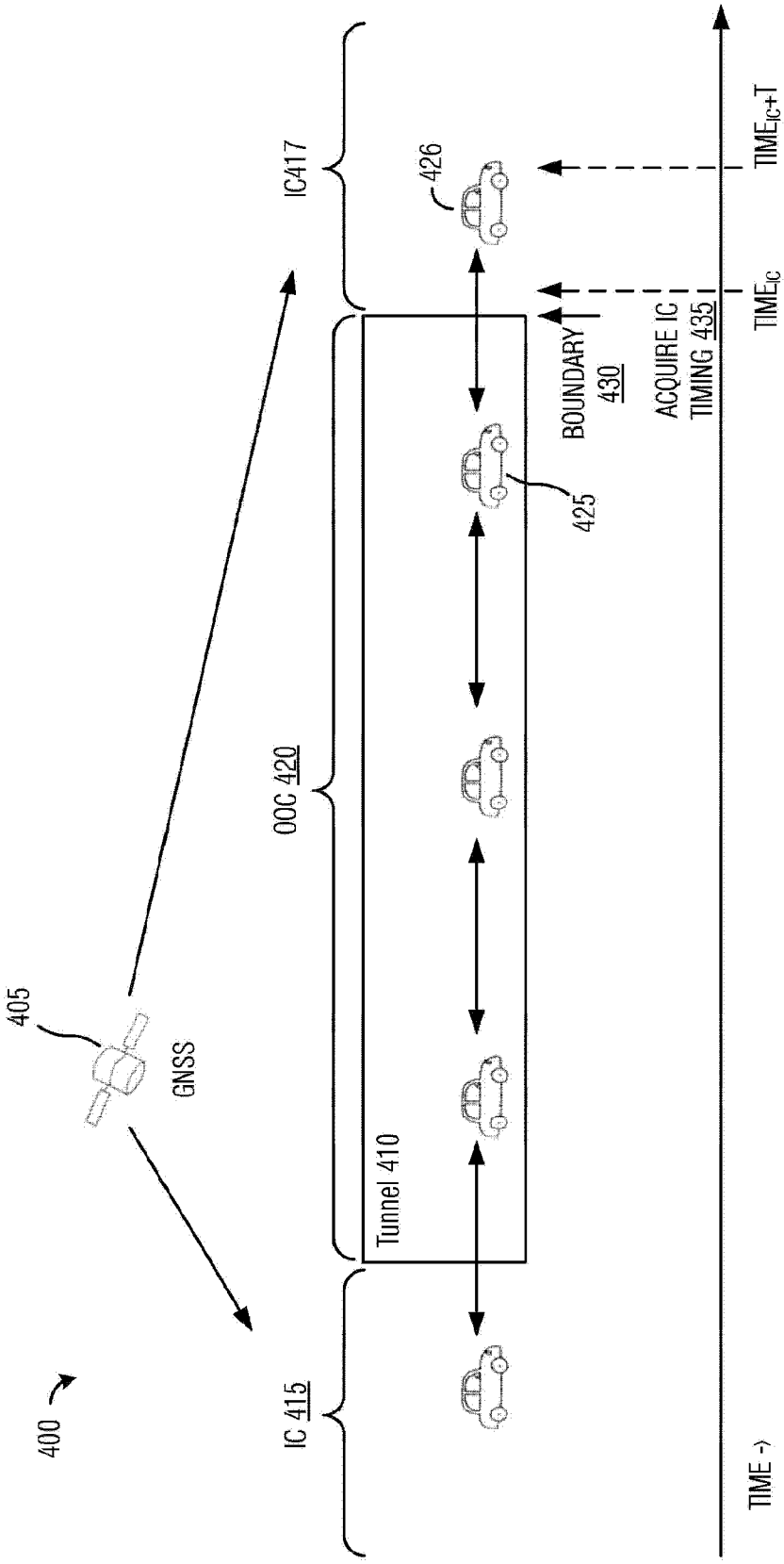

400
405
GNSS
IC 415
OOC 420
Tunnel 410
IC417
426
425
BOUNDARY 430
ACQUIRE IC TIMING 435
TIME$_{IC}$
TIME$_{IC}$+T
TIME ->

Fig. 4

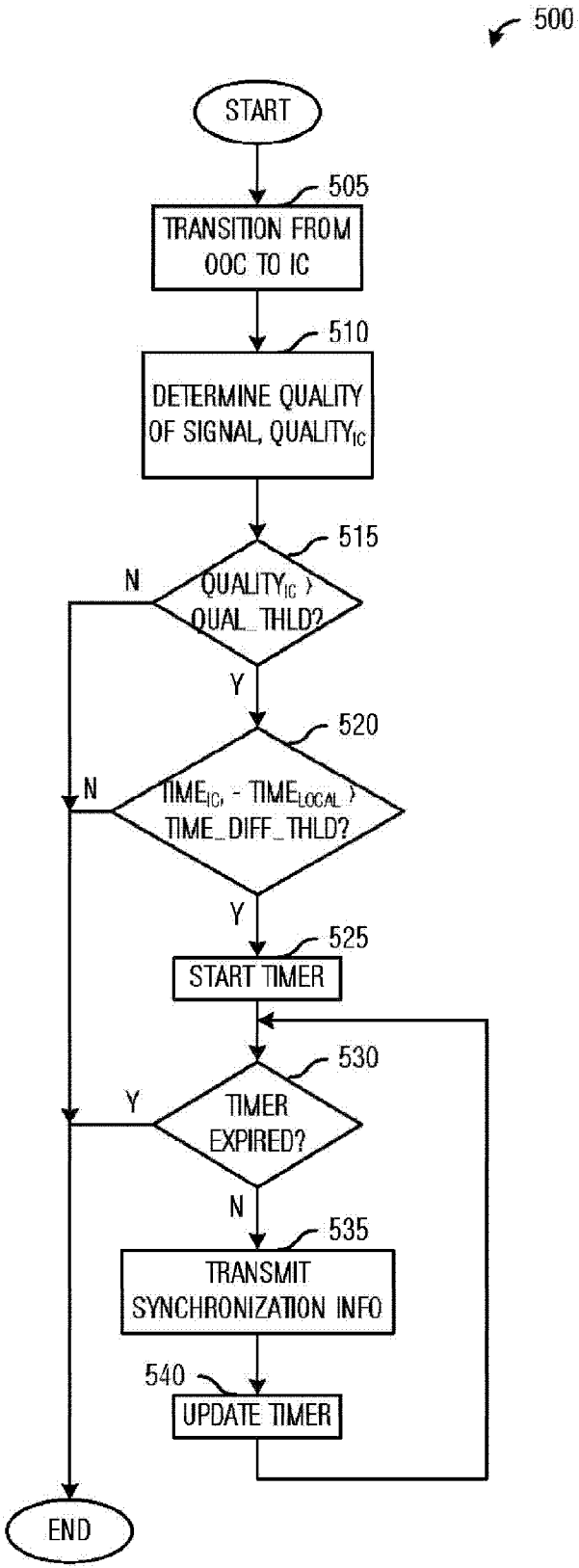

500
START
505
TRANSITION FROM OOC TO IC
510
DETERMINE QUALITY OF SIGNAL, QUALITY$_{IC}$
515
QUALITY$_{IC}$ > QUAL_THLD?
N
Y
520
TIME$_{IC}$ - TIME$_{LOCAL}$ > TIME_DIFF_THLD?
N
Y
525
START TIMER
530
TIMER EXPIRED?
Y
N
535
TRANSMIT SYNCHRONIZATION INFO
540
UPDATE TIMER
END

Fig. 5

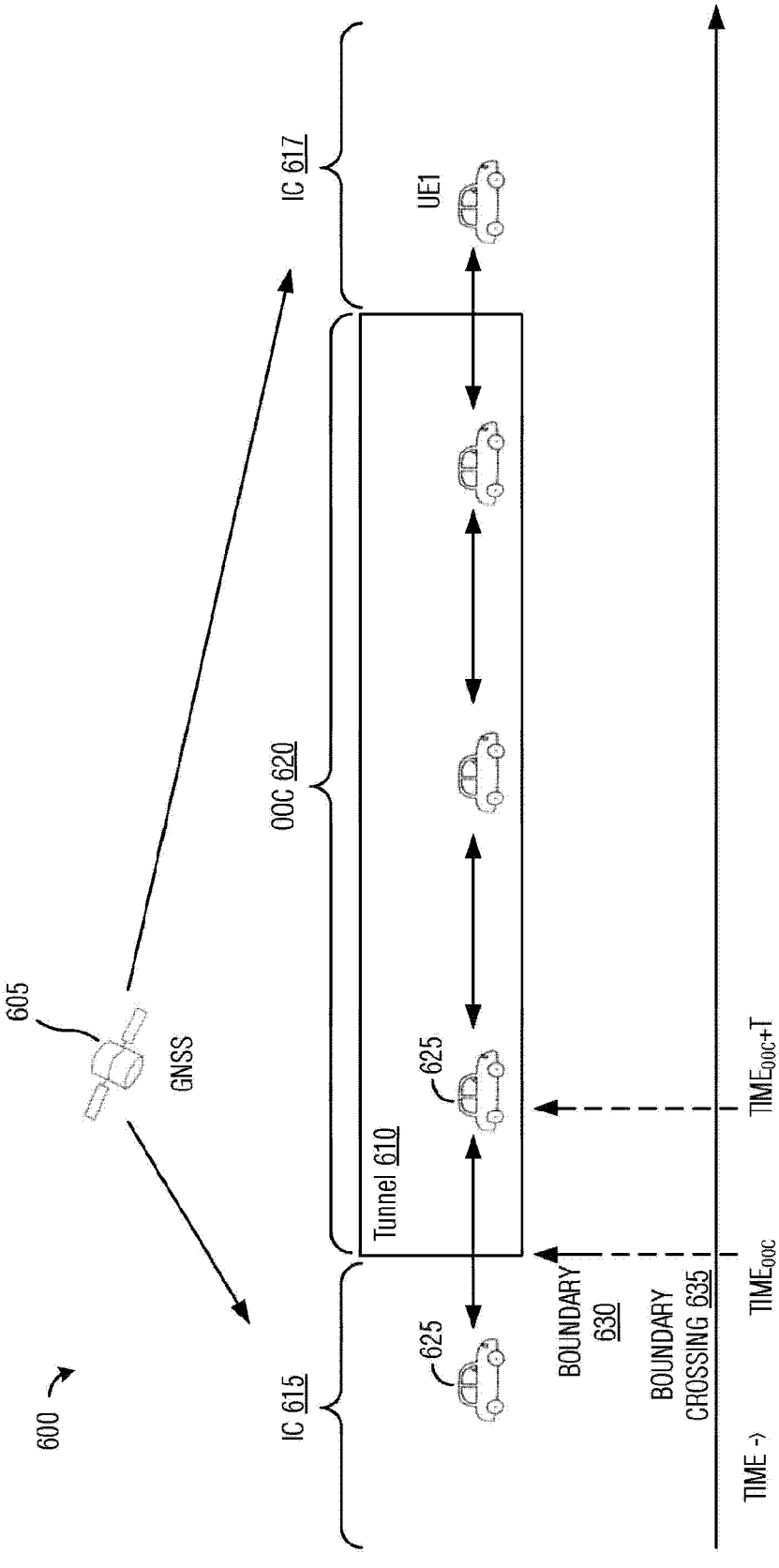

600
605
GNSS
IC 615
OOC 620
IC 617
Tunnel 610
UE1
625
625
BOUNDARY 630
BOUNDARY CROSSING 635
TIME ->
TIME$_{OOC}$
TIME$_{OOC}$+T

Fig. 6

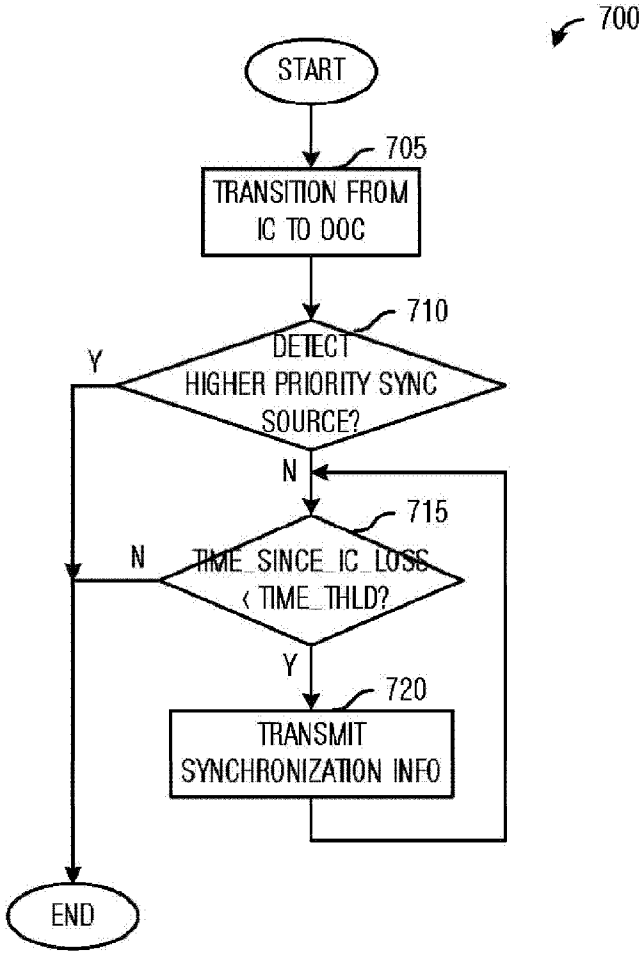

700
START
705
TRANSITION FROM IC TO OOC
710
DETECT HIGHER PRIORITY SYNC SOURCE?
Y
N
715
TIME_SINCE_IC_LOSS < TIME_THLD?
N
Y
720
TRANSMIT SYNCHRONIZATION INFO
END

Fig. 7

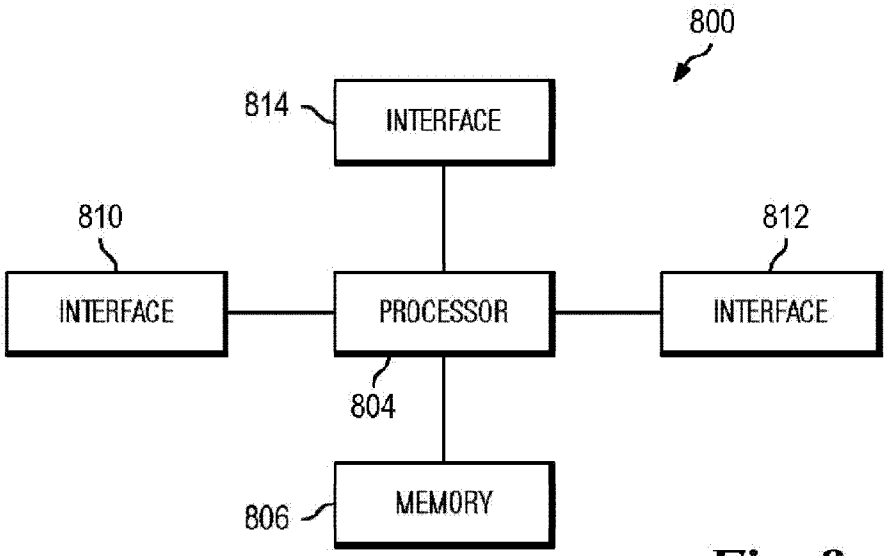

800
814
INTERFACE
810
812
INTERFACE
PROCESSOR
INTERFACE
804
806
MEMORY

Fig. 8

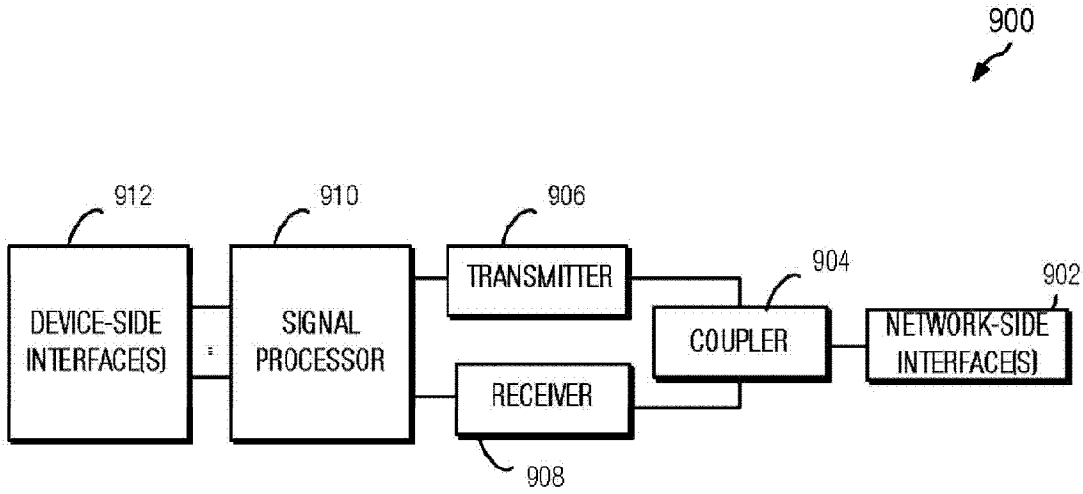

900
912
910
906
904
902
DEVICE-SIDE INTERFACE(S)
SIGNAL PROCESSOR
TRANSMITTER
COUPLER
NETWORK-SIDE INTERFACE(S)
RECEIVER
908

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/078624

A. CLASSIFICATION OF SUBJECT MATTER

H04W 56/00(2009.01)i

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)

H04W56; H04W88; H04Q7

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)

CNABS,CNTXT,CNKI,USTXT,VEN,3GPP FTP:synchronization, OOC, IC, coverage, change, out, D2D, V2V, RSRQ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015119429 A1 (LG ELECTRONICS INC) 13 August 2015 (2015-08-13) paragraphs [0125] to [0154]	1-23
A	WO 2015111851 A1 (SAMSUNG ELECTRONICS CO LTD) 30 July 2015 (2015-07-30) the whole document	1-23
A	WO 2014183104 A1 (HUAWEI TECH CO LTDET AL.) 13 November 2014 (2014-11-13) the whole document	1-23

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
12 May 2017	**22 June 2017**
Name and mailing address of the ISA/CN **STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China** Facsimile No. **(86-10)62019451**	Authorized officer **DUAN,Wei** Telephone No. **(86-10)62412036**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/078624

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2015119429 A1	13 August 2015	US 2017013575 A1	12 January 2017
		CN 105960821 A	21 September 2016
WO 2015111851 A1	30 July 2015	CN 104812058 A	29 July 2015
WO 2014183104 A1	13 November 2014	US 2014335853 A1	13 November 2014
		EP 2987361 A4	18 May 2016
		EP 2987361 A1	24 February 2016
		CN 105210417 A	30 December 2015