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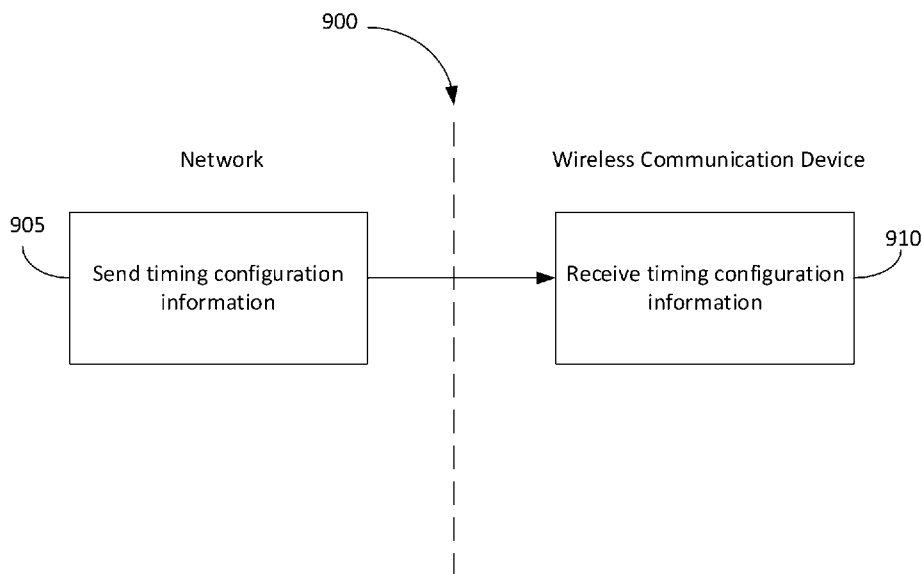


FIG. 9

(57) Abstract: At least one aspect of the present disclosure is directed to a wireless communication method. The wireless communication method can include a first wireless communication device sending a message including timing configuration assistance information for a sidelink communication to a second wireless communication device. The wireless communication method can include the first wireless communication device receiving a timing configuration information from a network.

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SYSTEM AND METHOD FOR PERFORMING SIDELINK COMMUNICATION FOR TIME-SENSITIVE NETWORKING

TECHNICAL FIELD

The disclosure relates generally to wireless communications, including but not limited to systems and methods for performing sidelink communication for time sensitive networking.

BACKGROUND

The standardization organization Third Generation Partnership Project (3GPP) is currently in the process of specifying a new Radio Interface called 5G New Radio (5G NR) as well as a Next Generation Packet Core Network (NG-CN or NGC). The 5G NR will have three main components: a 5G Access Network (5G-AN), a 5G Core Network (5GC), and a User Equipment (UE). In order to facilitate the enablement of different data services and requirements, the elements of the 5GC, also called Network Functions, have been simplified with some of them being software based, and some being hardware based, so that they could be adapted according to need. For industrial solutions, sidelink can increase reliability by providing an additional transmission path. There could then be both a device-to-network connection (NR-Uu) and a sidelink connection (NR-PC5). This increases redundancy, for instance, in the motion control use case, in which the failure of one communication path can be compensated for by switching to the other. However, this is not standardized in 3GPP and requires a solution involving dual-modem devices above the radio layers. However, in current technology, sidelink communication cannot support time Sensitive Communications (TSC) and Time Sensitive Networking (TSN) and different UEs cannot be synchronization with each other. So that deterministic communication cannot be supported for sidelink.

SUMMARY

The example embodiments disclosed herein are directed to solving the issues relating to one or more of the problems presented in the prior art, as well as providing additional features that will become readily apparent by reference to the following detailed description when taken in conjunction with the accompany drawings. In accordance with various embodiments, example systems, methods, devices and computer program products are disclosed herein. It is understood, however, that these embodiments are presented by way of example and are not limiting, and it will be apparent to those of ordinary skill in the art who read the present disclosure that various modifications to the disclosed embodiments can be made while remaining within the scope of this disclosure.

At least one aspect is directed to a system, method, apparatus, or a computer-readable medium of the following. A wireless communication method can include a first wireless communication device sending a message including timing configuration assistance information for a sidelink communication to a second wireless communication device. The wireless communication method can include the first wireless communication device receiving a timing configuration information from a network (e.g., network 100). The

timing configuration assistance information, related to a first clock of the first wireless communication device, can include at least one of a priority of the first clock, a class of the first clock, accuracy of the first clock, stabilization of the first clock, a Global Navigation Satellite System (GNSS) indication, a Time-Sensitive Networking (TSN) indication, a state of a Precision Time Protocol (PTP) port of the first wireless communication device, or a groupcast header indication.

The timing configuration information can include at least one of whether or not the first wireless communication device can serve as a source clock and send timing-related information to one or more other wireless communication devices, a priority of a first clock of the first wireless communication device, an identity of the first clock, or a type of the first clock. The wireless communication method can include the first wireless communication device receiving the timing configuration information, the timing configuration assistance information or a first capability message from the second wireless communication device. The first capability message includes whether the second wireless communication device supports sending or receiving timing information. The wireless communication method can include the first wireless communication device sending the timing configuration information, the timing configuration assistance information, or a second capability message to the second wireless communication device. The second capability message includes whether the first wireless communication device support sending or receiving timing information. The wireless communication method can include the first wireless communication device sending any of the received timing configuration information or the timing configuration assistance information to the network.

The wireless communication method can include the first wireless communication device determining to serve as a source clock and send timing-related information to one or more other wireless communication devices, in response to at least one of the following conditions being met. The conditions include the first wireless communication device supports sending the timing configuration information and the second wireless communication device supports receiving the timing configuration information, the first wireless communication device is a header User Equipment (UE), the priority of the first clock is higher than a priority of a second clock related to the second communication device, the class of the first clock is higher than a class of the second clock, the accuracy of the first clock is higher than accuracy of the second clock, the stabilization of the first clock is higher than stabilization of the second clock, the first wireless communication device directly synchronized to the GNSS, the first wireless communication device directly synchronized to a network node, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection, the first clock is a TSN timing GM, the PTP port is configured in Leader or Master state for the sidelink communication between the first wireless communication device and the second communication device, the PTP port is configured in Leader or Master state for a source/destination ID associated with the sidelink communication between the first wireless communication device and the second communication device, a synchronization source priority of the first wireless communication device is higher than a synchronization source priority of the second wireless communication device, synchronization sources of first wireless communication device and second wireless communication device are different, types of the synchronization sources of first wireless communication device and second wireless communication device are different, or identities of the synchronization sources of first wireless communication device and second wireless communication device are different.

The wireless communication method can include the first wireless communication device acquiring

by an AS layer of the first wireless communication device, from its NAS layer, at least one of the following information: a groupcast indication, a TSN indication, a state of a PTP port of the first wireless communication device, or the wireless communication device is a synchronization source. The wireless communication method can include the first wireless communication device determining to send the timing configuration information to the second wireless communication device, in response to at least one of the following condition being met: the first wireless communication device is a header UE, the first wireless communication device is a synchronization source, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection, the first clock is a TSN timing GM, or the PTP port is configured in Leader or Master state for a destination ID, D2.

The wireless communication method can include the first wireless communication device sending radio interface-related information which includes: referenceSFN and referenceTimeInfo. The radio interface-related information is used to determine time stamping. The radio interface-related information is carried by a Sidelink RRC message. The first wireless communication device sends the radio interface-related information periodically. The first wireless communication device sends the timing configuration information, in response to identifying any of the radio interface-related information has changed.

A wireless communication method can include first wireless communication device determining to serve as a source clock and send timing-related information to one or more other wireless communication devices. Prior to determining to serve as the source clock, the first wireless communication device receiving a message including timing configuration assistance information, timing configuration information, or the first capability message from a second wireless communication device. The first capability message include whether the second wireless communication device supports sending or receiving the timing-related information.

The wireless communication method can include first wireless communication device determining to serve as the source clock and send the timing-related information to the one or more other wireless communication devices, in response to at least one of the following condition being met: the first wireless communication device supports sending the timing configuration information and the second wireless communication device supports receiving the timing configuration information, the first wireless communication device is a header User Equipment (UE), the priority of the first clock is higher than a priority of a second clock related to the second communication device, the class of the first clock is higher than a class of the second clock, the accuracy of the first clock is higher than accuracy of the second clock, the stabilization of the first clock is higher than stabilization of the second clock, the first wireless communication device directly synchronized to the GNSS, the first wireless communication device directly synchronized to a network node, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection, the first clock is a TSN timing GM, the PTP port is configured in Leader or Master state for the sidelink communication between the first wireless communication device and the second communication device, the PTP port is configured in Leader or Master state for a source/destination ID associated with the sidelink communication between the first wireless communication device and the second communication device, a synchronization source priority of the first wireless communication device is higher than a synchronization source priority of the second wireless communication device, synchronization sources of first wireless communication device and second wireless communication device are different, types of the synchronization

sources of first wireless communication device and second wireless communication device are different, or identities of the synchronization sources of first wireless communication device and second wireless communication device are different.

The wireless communication method can include first wireless communication device determining to serve as the source clock and send the timing-related information to the one or more other wireless communication devices, in response to at least one of the following condition being met: the first wireless communication device is a header UE, the first wireless communication device is a synchronization source, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless communication, a clock of the first wireless communication device is connected to a TSN timing GM, or a PTP port of the first wireless communication device is configured in Leader or Master state for a destination ID, D2. The wireless communication method can include first wireless communication device sending radio interface-related information which includes: referenceSFN and referenceTimeInfo. The radio interface-related information is used to determine time stamping.

BRIEF DESCRIPTION OF THE DRAWINGS

Various example embodiments of the present solution are described in detail below with reference to the following figures or drawings. The drawings are provided for purposes of illustration only and merely depict example embodiments of the present solution to facilitate the reader's understanding of the present solution. Therefore, the drawings should not be considered limiting of the breadth, scope, or applicability of the present solution. It should be noted that for clarity and ease of illustration, these drawings are not necessarily drawn to scale.

FIG. 1 illustrates an example cellular communication network in which techniques disclosed herein may be implemented, in accordance with an embodiment of the present disclosure;

FIG. 2 illustrates a block diagram of an example base station and a user equipment device, in accordance with some embodiments of the present disclosure;

FIG. 3 illustrates an example method for user equipment (UE) to maintain the synchronized radio interface time via a network for a unicast case, in accordance with an embodiment of the present disclosure;

FIG. 4 illustrates an example method for UE to maintain the synchronized radio interface time without the network for the unicast case, in accordance with an embodiment of the present disclosure;

FIG. 5 illustrates an example method for UE to maintain the synchronized radio interface time with assistance from the network for the unicast case, in accordance with an embodiment of the present disclosure;

FIG. 6 illustrates an example method for UE to maintain the synchronized radio interface timing via a network for a groupcast case, in accordance with an embodiment of the present disclosure;

FIG. 7 illustrates an example method for an AS layer of the UE to maintain the synchronized radio interface timing, in accordance with an embodiment of the present disclosure;

FIG. 8 illustrates an example method for a NAS layer UE to maintain the synchronized radio

interface timing, in accordance with an embodiment of the present disclosure;

FIG. 9 illustrates a flowchart for performing sidelink communication for time sensitive networking, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

Mobile Communication Technology and Environment

FIG. 1 illustrates an example wireless communication network, and/or system, 100 in which techniques disclosed herein may be implemented, in accordance with an embodiment of the present disclosure. In the following discussion, the wireless communication network 100 may be any wireless network, such as a cellular network or a narrowband Internet of things (NB-IoT) network and is herein referred to as “network 100.” Such an example network 100 includes a base station 102 (hereinafter “BS 102”; also referred to as wireless communication node) and a user equipment device 104 (hereinafter “UE 104”; also referred to as wireless communication device) that can communicate with each other via a communication link 110 (e.g., a wireless communication channel), and a cluster of cells 126, 130, 132, 134, 136, 138 and 140 overlaying a geographical area 101. In FIG. 1, the BS 102 and UE 104 are contained within a respective geographic boundary of cell 126. Each of the other cells 130, 132, 134, 136, 138 and 140 may include at least one base station operating at its allocated bandwidth to provide adequate radio coverage to its intended users.

For example, the BS 102 may operate at an allocated channel transmission bandwidth to provide adequate coverage to the UE 104. The BS 102 and the UE 104 may communicate via a downlink radio frame 118, and an uplink radio frame 124 respectively. Each radio frame 118/124 may be further divided into sub-frames 120/127 which may include data symbols 122/128. In the present disclosure, the BS 102 and UE 104 are described herein as non-limiting examples of “communication nodes,” generally, which can practice the methods disclosed herein. Such communication nodes may be capable of wireless and/or wired communications, in accordance with various embodiments of the present solution.

FIG. 2 illustrates a block diagram of an example wireless communication system 200 for transmitting and receiving wireless communication signals (e.g., OFDM/OFDMA signals) in accordance with some embodiments of the present solution. The system 200 may include components and elements configured to support known or conventional operating features that need not be described in detail herein. In one illustrative embodiment, system 200 can be used to communicate (e.g., transmit and receive) data symbols in a wireless communication environment such as the wireless communication environment 100 of FIG. 1, as described above.

System 200 generally includes a base station 202 (hereinafter “BS 202”) and a user equipment device 204 (hereinafter “UE 204”). The BS 202 includes a BS (base station) transceiver module 210, a BS antenna 212, a BS processor module 214, a BS memory module 216, and a network communication module 218, each module being coupled and interconnected with one another as necessary via a data communication bus 220. The UE 204 includes a UE (user equipment) transceiver module 230, a UE antenna 232, a UE memory module 234, and a UE processor module 236, each module being coupled and interconnected with one another as necessary via a data communication bus 240. The BS 202 communicates with the UE 204 via a communication

channel 250, which can be any wireless channel or other medium suitable for transmission of data as described herein.

As would be understood by persons of ordinary skill in the art, system 200 may further include any number of modules other than the modules shown in FIG. 2. Those skilled in the art will understand that the various illustrative blocks, modules, circuits, and processing logic described in connection with the embodiments disclosed herein may be implemented in hardware, computer-readable software, firmware, or any practical combination thereof. To clearly illustrate this interchangeability and compatibility of hardware, firmware, and software, various illustrative components, blocks, modules, circuits, and steps are described generally in terms of their functionality. Whether such functionality is implemented as hardware, firmware, or software can depend upon the particular application and design constraints imposed on the overall system. Those familiar with the concepts described herein may implement such functionality in a suitable manner for each particular application, but such implementation decisions should not be interpreted as limiting the scope of the present disclosure.

In accordance with some embodiments, the UE transceiver 230 may be referred to herein as an "uplink" transceiver 230 that includes a radio frequency (RF) transmitter and a RF receiver each comprising circuitry that is coupled to the antenna 232. A duplex switch (not shown) may alternatively couple the uplink transmitter or receiver to the uplink antenna in time duplex fashion. Similarly, in accordance with some embodiments, the BS transceiver 210 may be referred to herein as a "downlink" transceiver 210 that includes a RF transmitter and a RF receiver each comprising circuitry that is coupled to the antenna 212. A downlink duplex switch may alternatively couple the downlink transmitter or receiver to the downlink antenna 212 in time duplex fashion. The operations of the two transceiver modules 210 and 230 may be coordinated in time such that the uplink receiver circuitry is coupled to the uplink antenna 232 for reception of transmissions over the wireless transmission link 250 at the same time that the downlink transmitter is coupled to the downlink antenna 212. Conversely, the operations of the two transceivers 210 and 230 may be coordinated in time such that the downlink receiver is coupled to the downlink antenna 212 for reception of transmissions over the wireless transmission link 250 at the same time that the uplink transmitter is coupled to the uplink antenna 232. In some embodiments, there is close time synchronization with a minimal guard time between changes in duplex direction.

The UE transceiver 230 and the base station transceiver 210 are configured to communicate via the wireless data communication link 250 and cooperate with a suitably configured RF antenna arrangement 212/232 that can support a particular wireless communication protocol and modulation scheme. In some illustrative embodiments, the UE transceiver 210 and the base station transceiver 210 are configured to support industry standards such as the Long-Term Evolution (LTE) and emerging 5G standards, and the like. It is understood, however, that the present disclosure is not necessarily limited in application to a particular standard and associated protocols. Rather, the UE transceiver 230 and the base station transceiver 210 may be configured to support alternate, or additional, wireless data communication protocols, including future standards or variations thereof.

In accordance with various embodiments, the BS 202 may be an evolved node B (eNB), a serving eNB, a target eNB, a femto station, or a pico station, for example. In some embodiments, the UE 204 may be

embodied in various types of user devices such as a mobile phone, a smart phone, a personal digital assistant (PDA), tablet, laptop computer, wearable computing device, etc. The processor modules 214 and 236 may be implemented, or realized, with a general-purpose processor, a content addressable memory, a digital signal processor, an application specific integrated circuit, a field programmable gate array, any suitable programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof, designed to perform the functions described herein. In this manner, a processor may be realized as a microprocessor, a controller, a microcontroller, a state machine, or the like. A processor may also be implemented as a combination of computing devices, e.g., a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a digital signal processor core, or any other such configuration.

Furthermore, the steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in firmware, in a software module executed by processor modules 214 and 236, respectively, or in any practical combination thereof. The memory modules 216 and 234 may be realized as RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. In this regard, memory modules 216 and 234 may be coupled to the processor modules 210 and 230, respectively, such that the processors modules 210 and 230 can read information from, and write information to, memory modules 216 and 234, respectively. The memory modules 216 and 234 may also be integrated into their respective processor modules 210 and 230. In some embodiments, the memory modules 216 and 234 may each include a cache memory for storing temporary variables or other intermediate information during execution of instructions to be executed by processor modules 210 and 230, respectively. Memory modules 216 and 234 may also each include non-volatile memory for storing instructions to be executed by the processor modules 210 and 230, respectively.

The network communication module 218 generally represents the hardware, software, firmware, processing logic, and/or other components of the base station 202 that enable bi-directional communication between base station transceiver 210 and other network components and communication nodes configured to communication with the base station 202. For example, network communication module 218 may be configured to support internet or WiMAX traffic. In a typical deployment, without limitation, network communication module 218 provides an 802.3 Ethernet interface such that base station transceiver 210 can communicate with a conventional Ethernet based computer network. In this manner, the network communication module 218 may include a physical interface for connection to the computer network (e.g., Mobile Switching Center (MSC)). The terms “configured for,” “configured to” and conjugations thereof, as used herein with respect to a specified operation or function, refer to a device, component, circuit, structure, machine, signal, etc., that is physically constructed, programmed, formatted and/or arranged to perform the specified operation or function.

The Open Systems Interconnection (OSI) Model (referred to herein as, “open system interconnection model”) is a conceptual and logical layout that defines network communication used by systems (e.g., wireless communication device, wireless communication node) open to interconnection and communication with other systems. The model is broken into seven subcomponents, or layers, each of which represents a conceptual collection of services provided to the layers above and below it. The OSI Model also

defines a logical network and effectively describes computer packet transfer by using different layer protocols. The OSI Model may also be referred to as the seven-layer OSI Model or the seven-layer model. In some embodiments, a first layer may be a physical layer. In some embodiments, a second layer may be a Medium Access Control (MAC) layer. In some embodiments, a third layer may be a Radio Link Control (RLC) layer. In some embodiments, a fourth layer may be a Packet Data Convergence Protocol (PDCP) layer. In some embodiments, a fifth layer may be a Radio Resource Control (RRC) layer. In some embodiments, a sixth layer may be a Non-Access Stratum (NAS) layer or an Internet Protocol (IP) layer, and the seventh layer being the other layer.

Various example embodiments of the present solution are described below with reference to the accompanying figures to enable a person of ordinary skill in the art to make and use the present solution. As would be apparent to those of ordinary skill in the art, after reading the present disclosure, various changes or modifications to the examples described herein can be made without departing from the scope of the present solution. Thus, the present solution is not limited to the example embodiments and applications described and illustrated herein. Additionally, the specific order or hierarchy of steps in the methods disclosed herein are merely example approaches. Based upon design preferences, the specific order or hierarchy of steps of the disclosed methods or processes can be re-arranged while remaining within the scope of the present solution. Thus, those of ordinary skill in the art will understand that the methods and techniques disclosed herein present various steps or acts in a sample order, and the present solution is not limited to the specific order or hierarchy presented unless expressly stated otherwise.

Systems and Methods for Performing Sidelink Communication for Time Sensitive Networking

In order to communicate time sensitive networking (TSN) type traffic, one important thing is that the communicated UEs should be synchronized with each other. According to current technology, the UE 104 can acquire the time information from the network side. However, there are not solutions to keep different UEs 104 synchronized with each other. For example, supposing the UE-1 and UE-2 establishes a PC5 connection and perform sidelink communication to transmit TSN type traffic, and UE-1 acquires time information from network node-1, UE-2 acquires time information from network node-2. If network node-1 and network node-2 have a different synchronization sources, then the UE-1 and UE-2 may be not synchronized.

A UE 104 may be involved in multiple types of TSN traffics or TSN time domains. Each TSN time domain is associated to one type of TSN traffic and a TSN time domain id. When UE-1 and UE-2 are involved in the same type of TSN service or traffic or TSN time domain-x or TSN port-y, and they have established a PC5 connection, they can communicate with TSN traffic via PC5 interface. The UE 104 can at least maintain one TSN time which associated with the TSN time domain id-x or TSN port-y, in addition, the UE 104 also maintain a timing information associated to radio interface.

Embodiment 1-1: Network Determine

FIG. 3 illustrates an example method 300 to determine the network 100 for a unicast case. At step 310, a first UE 104 can establish a PC5 link with a second UE 104. In some arrangements, a destination id of the PC5 link is D1 for the first UE 104. At step 320, the first UE 104 can receive the information described in

step 310 from the second UE 104, before the first UE 104 reports the information to the network 100. The information can further include a network 100 indication to indicate whether the UE 104 is directly or indirectly synchronized to network node or the network node identity, one or more synchronization source type indications to indicate synchronization source types of the UE 104 (e.g., GNSS or network node), and a priority of the synchronization sources. The first UE 104 can report the received information and a destination id D1 to the network 100.

At step 325, the first UE 104 can report information to the network 100. The information can include a priority of the clock, class of the clock, accuracy of the clock, stabilization of the clock (e.g., Offset Scaled LogVariance). The information can further include a Global Navigation Satellite System (GNSS) indication to indicate whether the UE 104 directly or indirectly synchronized to the GNSS. The information can further include a TSN indication to indicate whether the UE 104 is connecting to a TSN controller or TSN GM clock via wired or wireless connection. The TSN indication can indicate whether the clock of the first UE 104 is the TSN timing GM. The information can further include a state of PTP port of the first UE 104 (e.g., Leader or Master state, Follower or Slave state).

At step 330, the first UE 104 can receive the synchronization configuration information from the network 100. The configuration information include an indication to indicate that the UE 104 is a synchronization source for the link associated to the destination id D1 or that the UE 104 should send the synchronization information to the second UE 104 associated to the destination id D1. At step 340, if the first UE 104 is configured as the synchronization source or configured to send the timing information for radio interface, the UE 104 can send the timing information for radio interface to the second UE 104 associated to the destination id D1.

At step 350 the first UE 104 can send the timing information for radio interface to a second UE 104 associated with the destination id D1. The UE 104 may send the timing information for radio interface periodically or when a change occurs to the timing information. The timing information can include a referenceSFN field. The referenceSFN field can correspond to reference time information. The timing information can include a referenceTimeInfo field. The referenceTimeInfo field can indicate a time at an ending boundary of the system frame indicated by the referenceSFN field. The UE 104 can consider a frame (indicated by the referenceSFN) to be the frame which is nearest to the frame where a message (such as SL MIB or S-SSB) is received (past or future).

The timing information for radio interface can be used for time stamping. The first UE 104 or second UE 104 can send a directFrameNumber information and S-SSB to the network 100. The directFrameNumber can indicates the frame number in which S-SSB transmitted. The first UE 104 or second UE 104 can receive the directFrameNumber information and the S-SSB. The directFrameNumber indicates the frame number in which S-SSB transmitted. In this case, the directFrameNumber information and S-SSB may be sent by a third UE 105. The first UE 104 or second UE 104 can determine the frame number according to the GPS time, Coordinated Universal Time (UTC) or the local time.

The first UE 104 can send a PTP or gPTP message to the second UE 104 and generate an ingress timestamping (TSi) for a PTP or gPTP event (Sync) message. The first UE 104 can send the PTP or gPTP

message in response to the first UE 104 connecting with the TSN timing GM, to the clock of the first UE 104 corresponding to the TSN timing GM, or to the PTP port of the first UE 104 associating with the Leader or Master state. The first UE 104 can receive the PTP or gPTP message from the second UE 104 and use the timing information to create egress timestamping (TSe) for the PTP or gPTP event (Sync) messages. The first UE 104 can receive the PTP or gPTP message from the second UE 104 in response to the first UE 104 disconnecting from the TSN timing GM, from the clock of the first UE 104 not corresponding to the TSN timing GM, or from the PTP port of the first UE 104 associating with the Follower or Slave state. At step 360, the first UE 104 or second UE 104 can use a difference between TS_i and TS_e as a calculated residence time spent within the radio system for this PTP or gPTP message. Furthermore, the first UE 104 or second UE 104 can consider whether update the timing information of the clock.

Embodiment 1-2: UE 104 Determine (No Network)

FIG. 4 illustrates an example method 400 to determine the UE 104 without the network for the unicast case. At step 410, a first UE 104 can establish a PC5 link with a second UE, and the destination id of the PC5 link can be D1 for the first UE 104. At step 420, a capability message can be exchanged between the first UE 104 and the second UE 104. The capability message can include whether the UE 104 can support sending or receiving timing information. In some arrangements, step 420 does not occur in method 400.

At step 430, the first UE 104 can receive information from the second UE 104. The information can include any information described at step 435. In some arrangements, step 430 does not occur, but may occur after or before step 420. At step 435, the first UE 104 can send information to the second UE 104. The information can include a priority of the clock, class of the clock, accuracy of the clock, stabilization of the clock (e.g., Offset Scaled LogVariance). The information can further include a Global Navigation Satellite System (GNSS) indication to indicate whether the UE 104 directly or indirectly synchronized to the GNSS. The information can further include a TSN indication to indicate whether the UE 104 is connecting to a TSN controller or TSN GM clock via wired or wireless connection. The indication can indicate whether the clock of the first UE 104 is the TSN timing GM. The information can further include a state of PTP port of the first UE (e.g., Leader or Master state, Follower or Slave state). The information can further include a network 100 indication to indicate whether the UE 104 directly or indirectly synchronized to a network node or the network node identity, one or more synchronization source indications to indicate synchronization sources of the UE 104 (e.g., GNSS or network node), and a priority of the synchronization sources. The first UE 104 can report the received information and the destination id D1 to the network 100.

If the clock or synchronization sources Priority of the first UE 104 is equal to the clock or synchronization sources Priority of the second UE 104, and the clock Class of the first UE 104 is higher than the clock Class of the second UE 104, the first UE 104 can determine whether to send the timing information to the second UE 104. If the clock or synchronization sources Priority of the first UE 104 is equal to the clock or synchronization sources Priority of the second UE, if the clock Class of the first UE 104 is equal to the clock Class of the second UE, and the clock Accuracy of the first UE 104 is higher than the clock Accuracy of the second UE, then the first UE 104 can determine to send the timing information to the second UE 104. If the clock or synchronization sources Priority of the first UE 104 is equal to the clock or synchronization sources

Priority of the second UE 104, the clock Class of the first UE 104 is equal to the clock Class of the second UE 104, the clock Accuracy of the first UE 104 is equal to the clock Accuracy of the second UE 104, and the clock Stabilization of the first UE 104 is higher than the clock Stabilization of the second UE 104, the first UE 104 can determine to send the timing information to the second UE 104. Otherwise, the first UE 104 will not send the timing information to the second UE 104.

If the synchronization sources of first UE 104 and second UE 104 are the same, then neither the first UE 104 nor the second UE 104 may send the timing information to the network 100. Furthermore, both the first UE 104 and second UE 104 may use the respective timing information.

At step 440, the first UE 104 can determine whether to send the timing information to the second UE 104. The first UE 104 can determine to send the timing information to the second UE 104 in response to the satisfaction of one or more conditions. The conditions can include if the first UE 104 can support sending the timing information and the second UE 104 can support receiving the timing information, if a clock Priority of the first UE 104 is higher than the clock Priority of the second UE, if a clock Class of the first UE 104 is higher than the clock Class of the second UE, or if a clock Accuracy of the first UE 104 is higher than the clock Accuracy of the second UE 104.

The conditions can further include if a clock Stabilization of the first UE 104 is higher than the clock Stabilization of the second UE, if the first UE 104 directly synchronized to the GNSS, if the first UE 104 directly synchronized to the network node, if the first UE 104 is connecting to the TSN controller or TSN GM clock via wired or wireless connection, or if the clock of the first UE 104 is the TSN timing GM. The conditions can further include if a PTP port of the first UE 104 is configured in Leader or Master state for the link between the first UE 104 and second UE, if the PTP port of the first UE 104 is configured in Leader or Master state for the destination id D1 associated with the link between the first UE 104 and second UE, if the synchronization source priority of the first UE 104 is higher than the synchronization source priority of the second UE, or if the synchronization sources of first UE 104 and second UE 104 are different.

At step 450, the first UE 104 can send the timing information for radio interface to the second UE 104 associated with the destination id D1. The UE 104 may send the timing information for radio interface periodically or when a change occurs to the timing information. The timing information can include a referenceSFN field. The referenceSFN field can correspond to reference time information. The timing information can include a referenceTimeInfo field. The referenceTimeInfo field can indicate a time at the ending boundary of the system frame indicated by the referenceSFN field. The UE 104 can consider a frame (indicated by the referenceSFN) to be the frame which is nearest to the frame where a message is received (past or future).

The timing information for radio interface can use time stamping. The first UE 104 or the second UE 104 can send the directFrameNumber information and S-SSB to the network 100. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In one embodiment, the first UE 104 or the second UE 104 can receive the directFrameNumber information and S-SSB. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In this case, the directFrameNumber information and S-SSB may be sent by the third UE 104. In other embodiment, the first UE 104 or second UE 104 can determine the frame number according to the GPS time, Coordinated Universal Time (UTC) or the local time.

The first UE 104 can send a PTP or gPTP message to the second UE 104 and generate an ingress timestamping (TSi) for a PTP or gPTP event (Sync) message. The first UE 104 can send the PTP or gPTP message in response to the first UE 104 connecting with the TSN timing GM, the clock of the first UE 104 corresponding to the TSN timing GM, or the PTP port of the first UE 104 associating with the Leader or Master state. The first UE 104 can receive the PTP or gPTP message from the second UE 104 and use the timing information to create egress timestamping (TSe) for the PTP or gPTP event (Sync) messages. The first UE 104 can receive the PTP or gPTP message from the second UE 104 in response to the first UE 104 disconnecting from the TSN timing GM, the clock of the first UE 104 not corresponding to the TSN timing GM, or the PTP port of the first UE 104 associating with the Follower or Slave state. At step 460, the first UE 104 or second UE 104 can use the difference between TSi and TSe as a calculated residence time spent within the radio system for this PTP or gPTP message. Furthermore, the first UE 104 or second UE 104 can consider whether update the timing information of the clock.

Embodiment 1-3: UE 104 Determine (Network Assist)

FIG. 5 illustrates an example method to determine the UE 104 with the network for the unicast case. At step 510, a first UE 104 can establish a PC5 link with a second UE 104. In some arrangements, a destination id of the PC5 link is D1 for the first UE 104. At step 520, the first UE 104 can report information to the network 100. The information can include a priority of the clock, class of the clock, accuracy of the clock, stabilization of the clock (e.g., Offset Scaled LogVariance). The information can further include a Global Navigation Satellite System (GNSS) indication to indicate whether the UE 104 directly or indirectly synchronized to the GNSS. The information can further include a Time-Sensitive Networking (TSN) indication to indicate whether the UE 104 is connecting to a TSN controller or TSN GM clock via wired or wireless connection. The indication can indicate whether the clock of the first UE 104 is the TSN timing GM. The information can further include a state of PTP port of the first UE (e.g., Leader or Master state, Follower or Slave state).

At step 530, the first UE 104 can receive the synchronization configuration information from the network 100. The configuration information include a priority of the synchronization sources or the clock, a synchronization source identity, or a synchronization source type (e.g., GNSS or network node). At step 540, the first UE 104 can receive the priority of the synchronization information from the second UE 104. In some arrangements, step 545 may not occur. At step 545, the first UE 104 can send the priority of the synchronization information to the second UE 104. The synchronization information can be the same as the configuration information. At step 550, the first UE 104 can determine whether to send the timing information to the second UE 104. The first UE 104 can send the timing information to the second UE 104 if the synchronization source priority of the first UE 104 is higher than the synchronization source priority of the second UE 104, if the synchronization sources identity of first UE 104 and second UE 104 are different, or if the synchronization sources type of first UE 104 and second UE 104 are different. Otherwise, the first UE 104 will not send the timing information from the second UE 104.

If the synchronization source's identity of first UE 104 and second UE 104 are the same, neither the first UE 104 nor the second UE 104 can send the timing information. Furthermore, both the first UE 104 and second UE 104 can use the respective timing information. The first UE 104 can receive and use the timing

information from the second UE 104. At step 560, the first UE 104 can send the timing information for radio interface to the second UE 104 associated with the destination id D1. The UE 104 may send the timing information for radio interface periodically or when a change occurs to the timing information. The timing information can include a referenceSFN field. The referenceSFN field can correspond to reference time information. The timing information can include a referenceTimeInfo field. The referenceTimeInfo field can indicate a time at an ending boundary of the system frame indicated by the referenceSFN field. The UE 104 can consider a frame (indicated by the referenceSFN) to be the frame which is nearest to the frame where a message is received (past or future).

The timing information for radio interface can use time stamping. The first UE 104 or the second UE 104 can send the directFrameNumber information and S-SSB to the network 100. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In one embodiment, the first UE 104 or the second UE 104 can receive the directFrameNumber information and S-SSB. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In this case, the directFrameNumber information and S-SSB may be sent by a third UE 104. The first UE 104 or second UE 104 can determine the frame number according to the GPS time, Coordinated Universal Time (UTC) or the local time.

The first UE 104 can receive the PTP or gPTP message from the second UE 104 and use the timing information to create egress timestamping (TSe) for the PTP or gPTP event (Sync) messages. The first UE 104 can receive the PTP or gPTP message from the second UE 104 in response to the first UE 104 disconnecting from the TSN timing GM, the clock of the first UE 104 not corresponding to the TSN timing GM, or the PTP port of the first UE 104 associating with the Follower or Slave state. The first UE 104 can send a PTP or gPTP message to the second UE 104 and generate an ingress timestamping (TSi) for a PTP or gPTP event (Sync) message. The first UE 104 can send the PTP or gPTP message in response to the first UE 104 connecting with the TSN timing GM, the clock of the first UE 104 corresponding to the TSN timing GM, or the PTP port of the first UE 104 associating with the Leader or Master state. At step 570, the first UE 104 or second UE 104 can use the difference between TSi and TSe as a calculated residence time spent within the radio system for this PTP or gPTP message. Furthermore, the first UE 104 or second UE 104 can consider whether update the timing information of the clock.

In order to communicate TSN type traffic, an important aspect is that the communicated UEs may synchronize with each other. According to current technology, the UE 104 can acquire the synchronization information from the network 100. However, there are no solutions to keep different UEs synchronized with each other. For example, UE-1 and UE-2 are in the same group associated with destination id-D2 and perform sidelink groupcast communication to transmit TSN type traffic. UE-1 can acquire time information from network node-1 and UE-2 can acquire time information from network node-2. If network node-1 and network node-2 include a different source synchronization clock, then the UE-1 and UE-2 may not synchronize. Aspects of this disclosure include several solutions for a UE 104 on how to determine the synchronization source and how to send the synchronization information.

The UE 104 may be involved in multiple types of TSN traffics or TSN time domains. Each TSN time domain can associate with one type of TSN traffic and a TSN time domain id. UE-1 and UE-2 can be in

the same type of TSN service, traffic, TSN time domain-x, or TSN port-y. UE-1 and UE-2 can establish a PC5 connection for groupcast and can communicate with the TSN traffic. The UE 104 can at least maintain one TSN time associated with the TSN time domain id-x or the TSN port-y. The UE 104 can maintain timing information associated with the radio interface.

Embodiment 2-1: Network Determine

FIG. 6 illustrates an example method 600 to determine a network for a groupcast case. At step 610, a first UE 104 can establish a groupcast sidelink link with one or more second UE 104 and a destination id of the groupcast sidelink link is D2. At step 620, the first UE 104 can send information to one or more second UEs 104. The information can include a priority of the clock, class of the clock, accuracy of the clock, or stabilization of the clock (e.g., Offset Scaled LogVariance). The information can further include a GNSS indication to indicate whether the UE 104 directly or indirectly synchronized to the GNSS. The information can further include a TSN indication to indicate whether the UE 104 is connecting to a TSN controller or TSN GM clock via wired or wireless connection. The indication can indicate that the clock of the first UE 104 is the TSN timing GM. The information can further include a state of PTP port of the first UE 104 (e.g., Leader or Master state, Follower or Slave state). The information can further include a groupcast header indication to indicate whether the UE 104 is the group caster header for this destination D2.

At step 630, the first UE 104 can receive a synchronization configuration information from the network 100. The configuration information include an indication to indicate that the UE 104 is the synchronization source for the link associated to a destination id D2 or that the UE 104 should send the synchronization information to the one or more second UEs 104 associated to the destination id D2.

At step 640, if the first UE 104 is configured as synchronization source or configured to send the timing information for radio interface, the UE 104 can send the timing information for radio interface to the one or more second UEs 104 associated with the destination id D2.

At step 650, the first UE 104 can send the timing information for radio interface to the one or more second UEs 104 associated with the destination id D2. The UE 104 may send the timing information for radio interface periodically or when a change occurs to the timing information. The timing information can include a referenceSFN field. The referenceSFN field can correspond to reference time information. The timing information can include a referenceTimeInfo field. The referenceTimeInfo field can indicate a time at an ending boundary of the system frame indicated by the referenceSFN field. The UE 104 can consider a frame (indicated by the referenceSFN) to be the frame which is nearest to the frame where a message is received (past or future).

The timing information for radio interface can use time stamping. The first UE 104 or the one or more second UEs 104 can send the directFrameNumber information and S-SSB to the network 100. The directFrameNumber can indicate the frame number in which S-SSB transmitted. The first UE 104 or the one or more second UEs 104 can receive the directFrameNumber information and S-SSB. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In this case, the directFrameNumber information and S-SSB may be sent by the third UE 104. The first UE 104 or one or more second UEs 104 can determine the frame number according to the GPS time, Coordinated Universal Time (UTC) or the local time.

The first UE 104 can send a PTP or gPTP message to the one or more second UEs 104 and generate an ingress timestamping (TSi) for a PTP or gPTP event (Sync) message. The first UE 104 can send the PTP or gPTP message in response to the first UE 104 connecting with the TSN timing GM, the clock of the first UE 104 corresponding to the TSN timing GM, or the PTP port of the first UE 104 associating with the Leader or Master state. The first UE 104 can receive the PTP or gPTP message from the one or more second UEs 104 and use the timing information to create egress timestamping (TSe) for the PTP or gPTP event (Sync) messages. The first UE 104 can receive the PTP or gPTP message from the one or more second UEs 104 in response to the first UE 104 disconnecting from the TSN timing GM, the clock of the first UE 104 not corresponding to the TSN timing GM, or the PTP port of the first UE 104 associating with the Follower or Slave state. At step 660, the first UE 104 or one or more second UEs 104 can use the difference between TSi and TSe as a calculated residence time spent within the radio system for this PTP or gPTP message. Furthermore, the first UE 104 or one or more second UEs 104 can consider whether update the timing information of the clock.

Embodiment 2-2: UE AS Layer Determine

FIG. 7 illustrates an example method 700 to determine a UE 104 AS layer for the groupcast case. At step 710, a first UE 104 can establish a groupcast sidelink link with one or more second UE 104 and a destination id of the groupcast sidelink link is D2. At step 720, the first UE 104 can receive information to one or more second UEs 104. The information can include a priority of the clock, class of the clock, accuracy of the clock, stabilization of the clock (e.g., Offset Scaled LogVariance). The information can further include a GNSS indication to indicate whether the UE 104 directly or indirectly synchronized to the GNSS. The information can further include a Time-Sensitive Networking (TSN) indication to indicate whether the UE 104 is connecting to a TSN controller or TSN GM clock via wired or wireless connection. The indication can indicate whether the clock of the first UE 104 is the TSN timing GM, or the information can include a state of PTP port of the first UE 104 (e.g., Leader or Master state, Follower or Slave state), or the information can include a groupcast header indication to indicate whether the UE 104 is the group caster header for this destination D2. In some arrangements, step 720 may not occur.

At step 730, the first UE 104 can send information to one or more second UEs 104. The information can include a priority of the clock, class of the clock, accuracy of the clock, stabilization of the clock (e.g., Offset Scaled LogVariance). The information can include a GNSS indication to indicate whether the UE 104 directly or indirectly synchronized to the GNSS. The information can include a Time-Sensitive Networking (TSN) indication to indicate whether the UE 104 is connecting to a TSN controller or TSN GM clock via wired or wireless connection. The indication can indicate whether the clock of the first UE 104 is the TSN timing GM. The information can include a state of PTP port of the first UE 104 (e.g., Leader or Master state, Follower or Slave state) and a groupcast header indication to indicate whether the UE 104 is the group caster header for this destination D2.

At step 740, the first UE 104 can determine whether to send the timing information to the one or more second UEs 104. The first UE 104 determine to send the timing information to the one or more second UEs 104 in response to the satisfaction of one or more conditions. The conditions can include if the first UE 104 is a header UE 104, a clock Priority of the first UE 104 is higher than the clock Priority of the one or more second

UEs 104, a clock Class of the first UE 104 is higher than the clock Class of the one or more second UEs 104, or a clock Accuracy of the first UE 104 is higher than the clock Accuracy of the one or more second UEs 104.

The conditions can further include if a clock Stabilization of the first UE 104 is higher than the clock Stabilization of the one or more second UEs 104, the first UE 104 directly synchronized to the GNSS, the first UE 104 directly synchronized to the network node, the first UE 104 is connecting to the TSN controller or TSN GM clock via wired or wireless connection communication, or the clock of the first UE 104 is the TSN timing GM. The conditions can further include if a PTP port of the first UE 104 is configured in Leader or Master state for the link between the first UE 104 and one or more second UEs 104, the PTP port of the first UE 104 is configured in Leader or Master state for the destination id D2 associated with the link between the first UE 104 and one or more second UEs 104, the synchronization source priority of the first UE 104 is higher than the synchronization source priority of the one or more second UEs 104, or the synchronization sources of first UE 104 and one or more second UEs 104 are different.

If the clock or synchronization sources Priority of the first UE 104 is equal to the clock or synchronization sources Priority of the one or more second UEs 104, and the clock Class of the first UE 104 is higher than the clock Class of the one or more second UEs 104, the first UE 104 can determine whether to send the timing information to the one or more second UEs 104. If the clock or synchronization sources Priority of the first UE 104 is equal to the clock or synchronization sources Priority of the one or more second UEs 104, the clock Class of the first UE 104 is equal to the clock Class of the one or more second UEs 104, and the clock Accuracy of the first UE 104 is higher than the clock Accuracy of the one or more second UEs 104, the first UE 104 can determine to send the timing information to the one or more second UEs 104. If the clock or synchronization sources Priority of the first UE 104 is equal to the clock or synchronization sources Priority of the one or more second UEs 104, the clock Class of the first UE 104 is equal to the clock Class of the one or more second UEs 104, the clock Accuracy of the first UE 104 is equal to the clock Accuracy of the one or more second UEs 104, and the clock Stabilization of the first UE 104 is higher than the clock Stabilization of the one or more second UEs 104, the first UE 104 can determine to send the timing information to the one or more second UEs 104. Otherwise, the first UE 104 will not send the timing information to the one or more second UEs 104.

If the synchronization sources of first UE 104 and one or more second UEs 104 are the same, then neither the first UE 104 nor one or more second UEs 104 may send the timing information. Furthermore, both the first UE 104 and one or more second UEs 104 may use the respective timing information. At step 750, the first UE 104 can send the timing information for radio interface to a one or more second UEs 104 associated to a destination id D2. The UE 104 may send the timing information for radio interface periodically or when a change occurs to the timing information. The timing information can include a referenceSFN field. The referenceSFN field can correspond to reference time information. The timing information can include a referenceTimeInfo field. The referenceTimeInfo field can indicate a time at the ending boundary of the system frame indicated by the referenceSFN field. The UE 104 can consider a frame (indicated by the referenceSFN) to be the frame which is nearest to the frame where a message is received (past or future).

The timing information for radio interface can use time stamping. The first UE 104 or the one or

more second UEs 104 can send the directFrameNumber information and S-SSB to the network 100. The directFrameNumber can indicate the frame number in which S-SSB transmitted. The first UE 104 or the one or more second UEs 104 can receive the directFrameNumber information and S-SSB. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In this case, the directFrameNumber information and S-SSB may be sent by the third UE 104. The first UE 104 or one or more second UEs 104 can determine the frame number according to the GPS time, Coordinated Universal Time (UTC) or the local time.

Embodiment 2-3: UE NAS Layer Determine

FIG. 8 illustrates an example method 800 to determine a UE 104 NAS layer for the groupcast case. At step 810, a first UE 104 can establish a groupcast sidelink link with one or more second UE 104 and a destination id of the groupcast sidelink link is D2. At step 820, an AS layer of the first UE 104 can acquire information from a NAS layer of the first UE 104. The information can include a groupcast header indication to indicate that the UE 104 is the groupcast header for the destination D2 or a TSN indication to indicate that the UE 104 is connecting with a TSN controller or TSN GM clock via wired or wireless connection communication. The TSN indication can indicate that the clock of the first UE 104 is the TSN timing GM. The information can include a state of PTP port of the first UE 104 (e.g., Leader or Master state, Follower or Slave state), or the first UE 104 is the synchronization source.

At step 830, the first UE 104 can determine whether to send the timing information to the one or more second UEs 104. The first UE 104 determine to send the timing information to the one or more second UEs 104 in response to the satisfaction of one or more conditions. The conditions can include if the first UE 104 is a header UE 104, the first UE 104 is the synchronization source, the first UE 104 is connecting to the TSN controller or TSN GM clock via wired or wireless connection communication, or the clock of the first UE 104 is the TSN timing GM. The conditions can further include if a PTP port of the first UE 104 is configured in Leader or Master state for the link between the first UE 104 and one or more second UEs 104, the PTP port of the first UE 104 is configured in Leader or Master state for the destination id D2 associated with the link between the first UE 104 and one or more second UEs 104.

At step 840, the first UE 104 can send the timing information for radio interface to a one or more second UEs 104 associated to a destination id D2. The UE 104 may send the timing information for radio interface periodically or when a change occurs to the timing information. The timing information can include a referenceSFN field. The referenceSFN field can correspond to reference time information. The timing information can include a referenceTimeInfo field. The referenceTimeInfo field can indicate a time at the ending boundary of the system frame indicated by the referenceSFN field. The UE 104 can consider a frame (indicated by the referenceSFN) to be the frame which is nearest to the frame where a message is received (past or future).

The timing information for radio interface can use time stamping. The first UE 104 or the one or more second UEs 104 can send the directFrameNumber information and S-SSB to the network 100. The directFrameNumber can indicate the frame number in which S-SSB transmitted. The first UE 104 or the one or more second UEs 104 can receive the directFrameNumber information and S-SSB. The directFrameNumber can indicate the frame number in which S-SSB transmitted. In this case, the directFrameNumber information and S-SSB may be sent by the third UE 104. The first UE 104 or one or more second UEs 104 can determine the frame

number according to the GPS time, Coordinated Universal Time (UTC) or the local time.

FIG. 9 illustrates a flowchart 900 for performing sidelink communication for time sensitive networking. The method 900 may be executed by any one or more of the components and devices detailed herein in conjunction with FIGs. 1–2. In overview, the method 900 may be performed by a wireless communication node (e.g., a base station (BS) 102), in some embodiments. Additional, fewer, or different operations may be performed in the method 900 depending on the embodiment. At least one aspect of the operations is directed to a system, method, apparatus, or a computer-readable medium.

A wireless communication method can include a first wireless communication device sending a message including timing configuration assistance information for a sidelink communication to a second wireless communication device. The wireless communication method can include the first wireless communication device receiving a timing configuration information from a network (e.g., network 100). The timing configuration assistance information, related to a first clock of the first wireless communication device, can include at least one of a priority of the first clock, a class of the first clock, accuracy of the first clock, stabilization of the first clock, a Global Navigation Satellite System (GNSS) indication, a Time-Sensitive Networking (TSN) indication, a state of a Precision Time Protocol (PTP) port of the first wireless communication device, or a groupcast header indication.

The timing configuration information can include at least one of whether or not the first wireless communication device can serve as a source clock and send timing-related information to one or more other wireless communication devices, a priority of a first clock of the first wireless communication device, an identity of the first clock, or a type of the first clock. The wireless communication method can include the first wireless communication device receiving the timing configuration information, the timing configuration assistance information or a first capability message from the second wireless communication device. The first capability message includes whether the second wireless communication device supports sending or receiving timing information. The wireless communication method can include the first wireless communication device sending the timing configuration information, the timing configuration assistance information, or a second capability message to the second wireless communication device. The second capability message includes whether the first wireless communication device support sending or receiving timing information. The wireless communication method can include the first wireless communication device sending any of the received timing configuration information or the timing configuration assistance information to the network.

The wireless communication method can include the first wireless communication device determining to serve as a source clock and send timing-related information to one or more other wireless communication devices, in response to at least one of the following conditions being met. The conditions include the first wireless communication device supports sending the timing configuration information and the second wireless communication device supports receiving the timing configuration information, the first wireless communication device is a header User Equipment (UE), the priority of the first clock is higher than a priority of a second clock related to the second communication device, the class of the first clock is higher than a class of the second clock, the accuracy of the first clock is higher than accuracy of the second clock, the stabilization of the first clock is higher than stabilization of the second clock, the first wireless communication device directly synchronized to the GNSS, the first wireless communication device directly synchronized to a network node, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or

wireless connection, the first clock is a TSN timing GM, the PTP port is configured in Leader or Master state for the sidelink communication between the first wireless communication device and the second communication device, the PTP port is configured in Leader or Master state for a source/destination ID associated with the sidelink communication between the first wireless communication device and the second communication device, a synchronization source priority of the first wireless communication device is higher than a synchronization source priority of the second wireless communication device, synchronization sources of first wireless communication device and second wireless communication device are different, types of the synchronization sources of first wireless communication device and second wireless communication device are different, or identities of the synchronization sources of first wireless communication device and second wireless communication device are different.

The wireless communication method can include the first wireless communication device acquiring by an AS layer of the first wireless communication device, from its NAS layer, at least one of the following information: a groupcast indication, a TSN indication, a state of a PTP port of the first wireless communication device, or the wireless communication device is a synchronization source. The wireless communication method can include the first wireless communication device determining to send the timing configuration information to the second wireless communication device, in response to at least one of the following condition being met: the first wireless communication device is a header UE, the first wireless communication device is a synchronization source, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection, the first clock is a TSN timing GM, or the PTP port is configured in Leader or Master state for a destination ID, D2.

The wireless communication method can include the first wireless communication device sending radio interface-related information which includes: referenceSFN and referenceTimeInfo. The radio interface-related information is used to determine time stamping. The radio interface-related information is carried by a Sidelink RRC message. The first wireless communication device sends the radio interface-related information periodically. The first wireless communication device sends the timing configuration information, in response to identifying any of the radio interface-related information has changed.

A wireless communication method can include first wireless communication device determining to serve as a source clock and send timing-related information to one or more other wireless communication devices. Prior to determining to serve as the source clock, the first wireless communication device receiving a message including timing configuration assistance information, timing configuration information, or the first capability message from a second wireless communication device. The first capability message include whether the second wireless communication device supports sending or receiving the timing-related information.

The wireless communication method can include first wireless communication device determining to serve as the source clock and send the timing-related information to the one or more other wireless communication devices, in response to at least one of the following condition being met: the first wireless communication device supports sending the timing configuration information and the second wireless communication device supports receiving the timing configuration information, the first wireless communication device is a header User Equipment (UE), the priority of the first clock is higher than a priority of a second clock related to the second communication device, the class of the first clock is higher than a class of the second clock,

the accuracy of the first clock is higher than accuracy of the second clock, the stabilization of the first clock is higher than stabilization of the second clock, the first wireless communication device directly synchronized to the GNSS, the first wireless communication device directly synchronized to a network node, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection, the first clock is a TSN timing GM, the PTP port is configured in Leader or Master state for the sidelink communication between the first wireless communication device and the second communication device, the PTP port is configured in Leader or Master state for a source/destination ID associated with the sidelink communication between the first wireless communication device and the second communication device, a synchronization source priority of the first wireless communication device is higher than a synchronization source priority of the second wireless communication device, synchronization sources of first wireless communication device and second wireless communication device are different, types of the synchronization sources of first wireless communication device and second wireless communication device are different, or identities of the synchronization sources of first wireless communication device and second wireless communication device are different.

The wireless communication method can include first wireless communication device determining to serve as the source clock and send the timing-related information to the one or more other wireless communication devices, in response to at least one of the following condition being met: the first wireless communication device is a header UE, the first wireless communication device is a synchronization source, the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless communication, a clock of the first wireless communication device is connected to a TSN timing GM, or a PTP port of the first wireless communication device is configured in Leader or Master state for a destination ID, D2. The wireless communication method can include first wireless communication device sending radio interface-related information which includes: referenceSFN and referenceTimeInfo. The radio interface-related information is used to determine time stamping.

While various embodiments of the present solution have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. Likewise, the various diagrams may depict an example architectural or configuration, which are provided to enable persons of ordinary skill in the art to understand example features and functions of the present solution. Such persons would understand, however, that the solution is not restricted to the illustrated example architectures or configurations but can be implemented using a variety of alternative architectures and configurations. Additionally, as would be understood by persons of ordinary skill in the art, one or more features of one embodiment can be combined with one or more features of another embodiment described herein. Thus, the breadth and scope of the present disclosure should not be limited by any of the above-described illustrative embodiments.

It is also understood that any reference to an element herein using a designation such as "first," "second," and so forth does not generally limit the quantity or order of those elements. Rather, these designations can be used herein as a convenient means of distinguishing between two or more elements or instances of an element. Thus, a reference to first and second elements does not mean that only two elements can be employed, or that the first element must precede the second element in some manner.

Additionally, a person having ordinary skill in the art would understand that information and signals can be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits and symbols, for example, which may be referenced in the above description can be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

A person of ordinary skill in the art would further appreciate that any of the various illustrative logical blocks, modules, processors, means, circuits, methods and functions described in connection with the aspects disclosed herein can be implemented by electronic hardware (e.g., a digital implementation, an analog implementation, or a combination of the two), firmware, various forms of program or design code incorporating instructions (which can be referred to herein, for convenience, as "software" or a "software module"), or any combination of these techniques. To clearly illustrate this interchangeability of hardware, firmware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware, firmware or software, or a combination of these techniques, depends upon the particular application and design constraints imposed on the overall system. Skilled artisans can implement the described functionality in various ways for each particular application, but such implementation decisions do not cause a departure from the scope of the present disclosure.

Furthermore, a person of ordinary skill in the art would understand that various illustrative logical blocks, modules, devices, components and circuits described herein can be implemented within or performed by an integrated circuit (IC) that can include a general-purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, or any combination thereof. The logical blocks, modules, and circuits can further include antennas and/or transceivers to communicate with various components within the network or within the device. A general-purpose processor can be a microprocessor, but in the alternative, the processor can be any conventional processor, controller, or state machine. A processor can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other suitable configuration to perform the functions described herein.

If implemented in software, the functions can be stored as one or more instructions or code on a computer-readable medium. Thus, the steps of a method or algorithm disclosed herein can be implemented as software stored on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that can be enabled to transfer a computer program or code from one place to another. A storage media can be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer.

In this document, the term "module" as used herein, refers to software, firmware, hardware, and any combination of these elements for performing the associated functions described herein. Additionally, for

purpose of discussion, the various modules are described as discrete modules, however, as would be apparent to one of ordinary skill in the art, two or more modules may be combined to form a single module that performs the associated functions according to embodiments of the present solution.

Additionally, memory or other storage, as well as communication components, may be employed in embodiments of the present solution. It will be appreciated that, for clarity purposes, the above description has described embodiments of the present solution with reference to different functional units and processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processing logic elements or domains may be used without detracting from the present solution. For example, functionality illustrated to be performed by separate processing logic elements, or controllers, may be performed by the same processing logic element, or controller. Hence, references to specific functional units are only references to a suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

Various modifications to the embodiments described in this disclosure will be readily apparent to those skilled in the art, and the general principles defined herein can be applied to other embodiments without departing from the scope of this disclosure. Thus, the disclosure is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the novel features and principles disclosed herein, as recited in the claims below.

C L A I M S

1. A wireless communication method, comprising:
sending, by a first wireless communication device, a message including timing configuration assistance information for a sidelink communication, and
receiving, by the first wireless communication device from a network, timing configuration information.
2. The wireless communication method of claim 1, wherein the timing configuration assistance information, related to a first clock of the first wireless communication device, can include at least one of:
a priority of the first clock,
a class of the first clock,
accuracy of the first clock,
stabilization of the first clock,
a Global Navigation Satellite System (GNSS) indication,
a Time-Sensitive Networking (TSN) indication,
a state of a Precision Time Protocol (PTP) port of the first wireless communication device, or
a groupcast header indication.
3. The wireless communication method of claim 1, wherein the timing configuration information can include at least one of:
whether or not the first wireless communication device can serve as a source clock and send timing-related information to one or more other wireless communication devices,
a priority of a first clock of the first wireless communication device,
an identity of the first clock, or
a type of the first clock.
4. The wireless communication method of claim 2, further comprising:
receiving, by the first wireless communication device from a second wireless communication device, the timing configuration information, the timing configuration assistance information or a first capability message,
wherein the first capability message includes whether the second wireless communication device supports sending or receiving timing information.
5. The wireless communication method of claim 2, further comprising:
sending, by the first wireless communication device to a second wireless communication device, the timing configuration information, the timing configuration assistance information, or a second capability message,
wherein the second capability message includes whether the first wireless communication device support sending or receiving timing information.
6. The wireless communication method of claim 4, further comprising:
sending, by the first wireless communication device to the network, any of the received timing

configuration information or the timing configuration assistance information.

7. The wireless communication method of any of claims 1 to 5, further comprising:

determining, by the first wireless communication device to serve as a source clock and send timing-related information to one or more other wireless communication devices, in response to at least one of the following condition being met:

the first wireless communication device supports sending the timing configuration information and the second wireless communication device supports receiving the timing configuration information,

the first wireless communication device is a header User Equipment (UE),

the priority of the first clock is higher than a priority of a second clock related to the second communication device,

the class of the first clock is higher than a class of the second clock,

the accuracy of the first clock is higher than accuracy of the second clock,

the stabilization of the first clock is higher than stabilization of the second clock,

the first wireless communication device directly synchronized to the GNSS,

the first wireless communication device directly synchronized to a network node,

the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection,

the first clock is a TSN timing GM,

the PTP port is configured in Leader or Master state for the sidelink communication between the first wireless communication device and the second communication device,

the PTP port is configured in Leader or Master state for a source/destination ID associated with the sidelink communication between the first wireless communication device and the second communication device,

a synchronization source priority of the first wireless communication device is higher than a synchronization source priority of the second wireless communication device,

synchronization sources of first wireless communication device and second wireless communication device are different,

types of the synchronization sources of first wireless communication device and second wireless communication device are different, or

identities of the synchronization sources of first wireless communication device and second wireless communication device are different.

8. The wireless communication method of claim 1, further comprising:

acquiring, by an AS layer of the first wireless communication device, from its NAS layer, at least one of the following information:

a groupcast indication,

a TSN indication,

a state of a PTP port of the first wireless communication device, or

the wireless communication device is a synchronization source.

9. The wireless communication method of any of claims 1 to 3, further comprising:
determining, by the first wireless communication device, to send the timing configuration information to the second wireless communication device, in response to at least one of the following condition being met:
the first wireless communication device is a header UE,
the first wireless communication device is a synchronization source,
the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection,
the first clock is a TSN timing GM, or
the PTP port is configured in Leader or Master state for a destination ID, D2.
10. The wireless communication method of claim 1, further comprising:
sending, by the first wireless communication device, radio interface-related information which includes at least one of: referenceSFN and referenceTimeInfo.
11. The wireless communication method of claim 10, wherein the radio interface-related information is used to determine time stamping.
12. The wireless communication method of claim 10, wherein the radio interface-related information is carried by a Sidelink RRC message.
13. The wireless communication method of claim 10, wherein the first wireless communication device sends the radio interface-related information periodically.
14. The wireless communication method of claim 10, wherein the first wireless communication device sends the timing configuration information, in response to identifying any of the radio interface-related information or timing information has changed.
15. A wireless communication method, comprising:
determining, by a first wireless communication device, to serve as a source clock and send timing-related information to one or more other wireless communication devices.
16. The wireless communication method of claim 15, prior to determining to serve as the source clock, further comprising:
receiving, by the first wireless communication device from a second wireless communication device, a message including timing configuration assistance information, timing configuration information, or the first capability message, wherein the first capability message include whether the second wireless communication device supports sending or receiving the timing-related information.
17. The wireless communication method of claim 15 or 16, further comprising:
determining to serve as the source clock and send the timing-related information to the one or more other wireless communication devices, in response to at least one of the following condition being met:
the first wireless communication device supports sending the timing configuration information
and the second wireless communication device supports receiving the timing configuration information,

the first wireless communication device is a header User Equipment (UE),
the priority of the first clock is higher than a priority of a second clock related to the second communication device,
the class of the first clock is higher than a class of the second clock,
the accuracy of the first clock is higher than accuracy of the second clock,
the stabilization of the first clock is higher than stabilization of the second clock,
the first wireless communication device directly synchronized to the GNSS,
the first wireless communication device directly synchronized to a network node,
the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless connection,
the first clock is a TSN timing GM,
the PTP port is configured in Leader or Master state for the sidelink communication between the first wireless communication device and the second communication device,
the PTP port is configured in Leader or Master state for a source/destination ID associated with the sidelink communication between the first wireless communication device and the second communication device,
a synchronization source priority of the first wireless communication device is higher than a synchronization source priority of the second wireless communication device,
synchronization sources of first wireless communication device and second wireless communication device are different,
types of the synchronization sources of first wireless communication device and second wireless communication device are different, or
identities of the synchronization sources of first wireless communication device and second wireless communication device are different.

18. The wireless communication method of claim 15 or 16, further comprising:
determining to serve as the source clock and send the timing-related information to the one or more other wireless communication devices, in response to at least one of the following condition being met:
the first wireless communication device is a header UE,
the first wireless communication device is a synchronization source,
the first wireless communication device has connected with a TSN controller or TSN GM clock via a wired or wireless communication,
a clock of the first wireless communication device is connected to a TSN timing GM, or
a PTP port of the first wireless communication device is configured in Leader or Master state for a destination ID, D2.
19. The wireless communication method of claim 15, further comprising:
sending, by the first wireless communication device, radio interface-related information which includes: referenceSFN and referenceTimeInfo.
20. The wireless communication method of claim 19, wherein the radio interface-related information is

used to determine time stamping.

21. A wireless communication method, comprising:
sending, by the network to the first wireless communication device, timing configuration information.
22. A wireless communications apparatus comprising a processor and a memory, wherein the processor is configured to read code from the memory and implement a method recited in any of claims 1 to 20.
23. A computer program product comprising a computer-readable program medium code stored thereupon, the code, when executed by a processor, causing the processor to implement a method recited in any of claims 1 to 20.

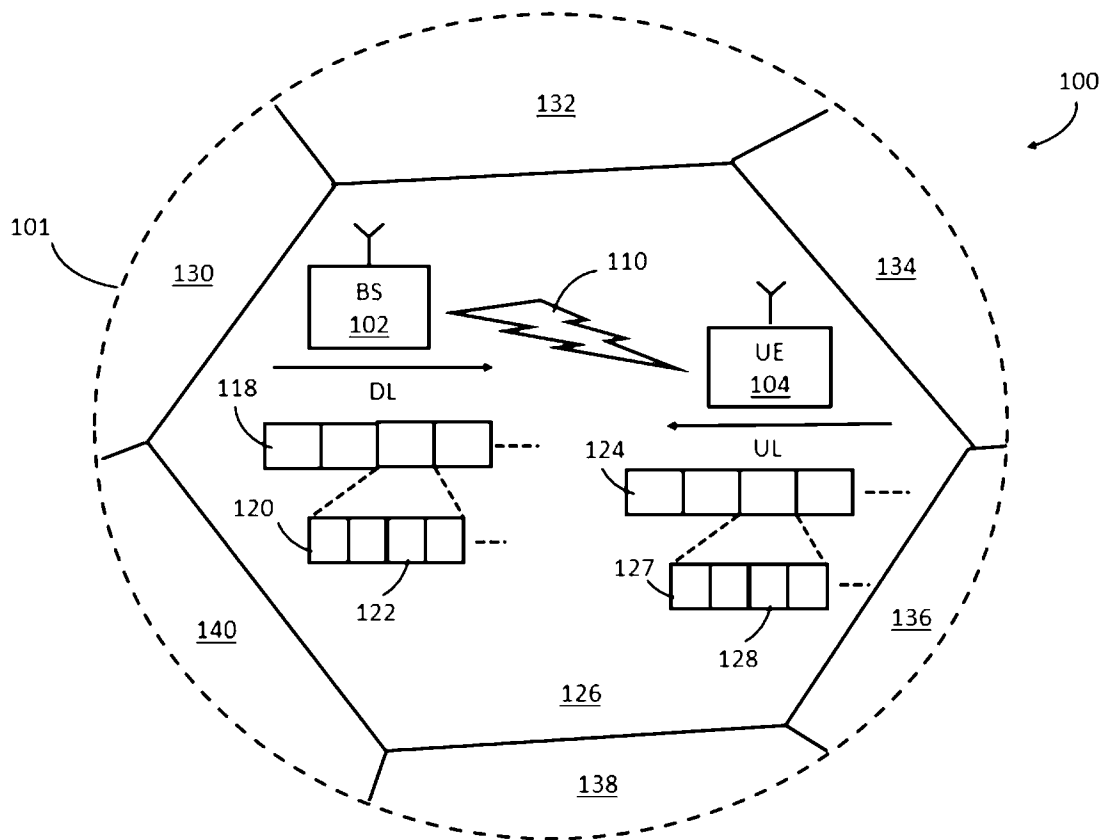


FIG. 1

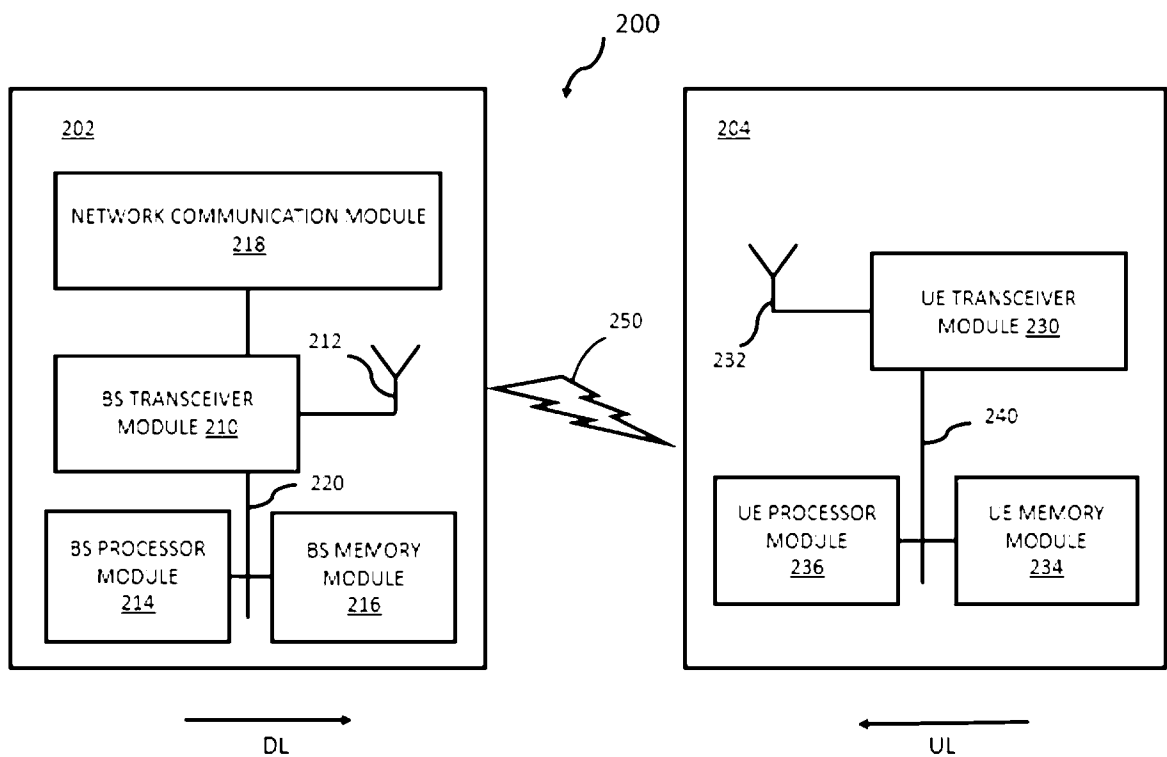


FIG. 2

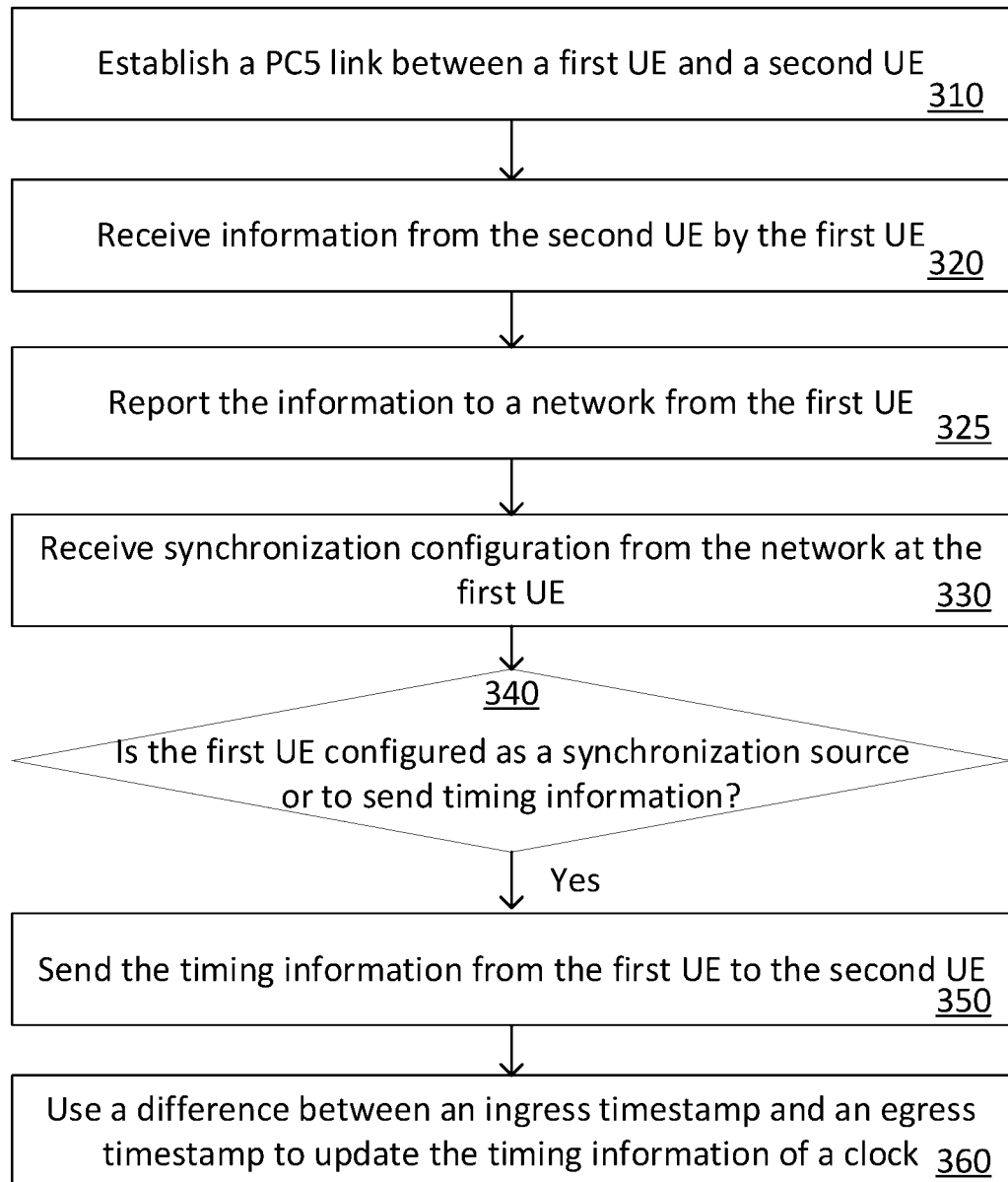
300

FIG. 3

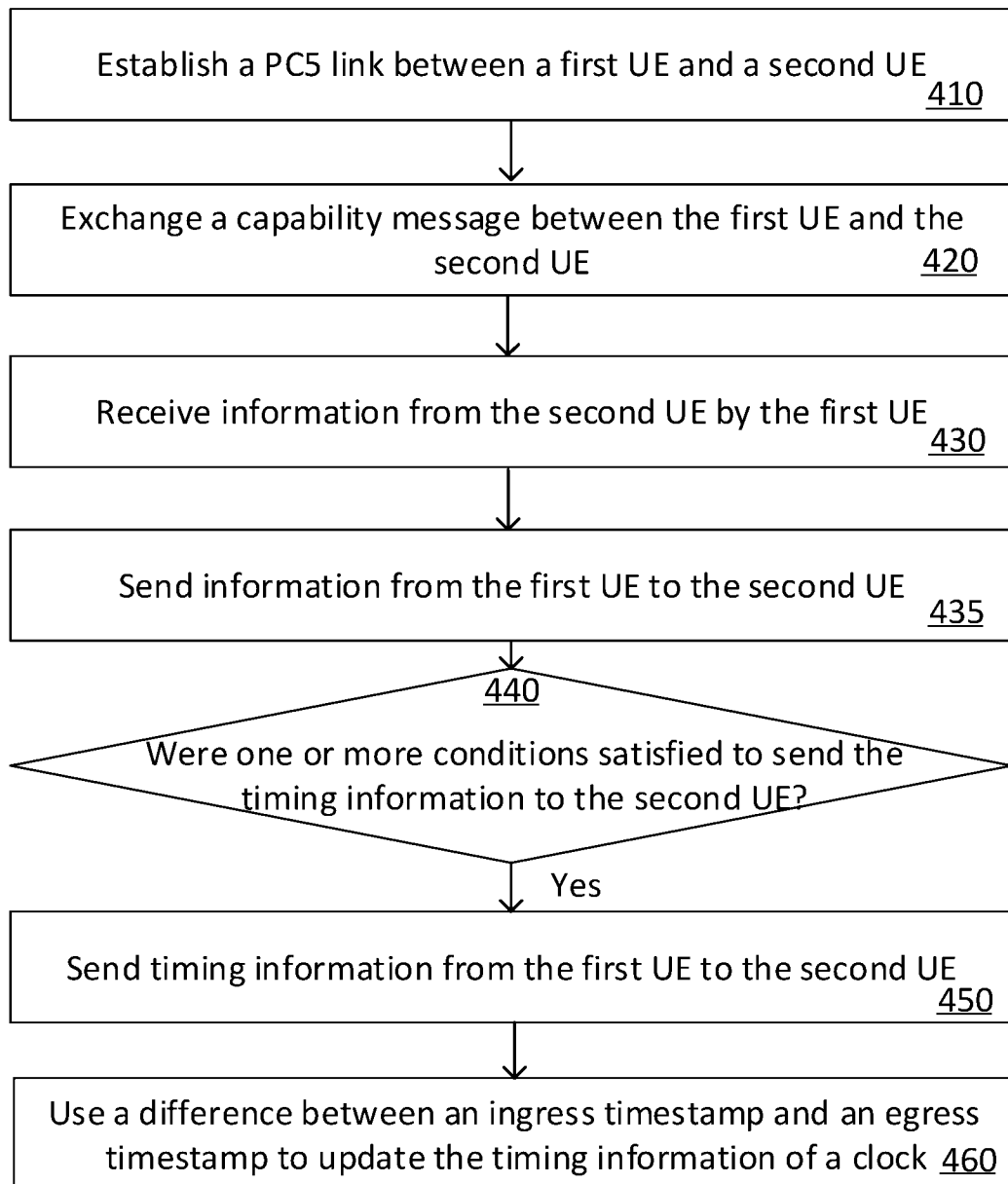
400

FIG. 4

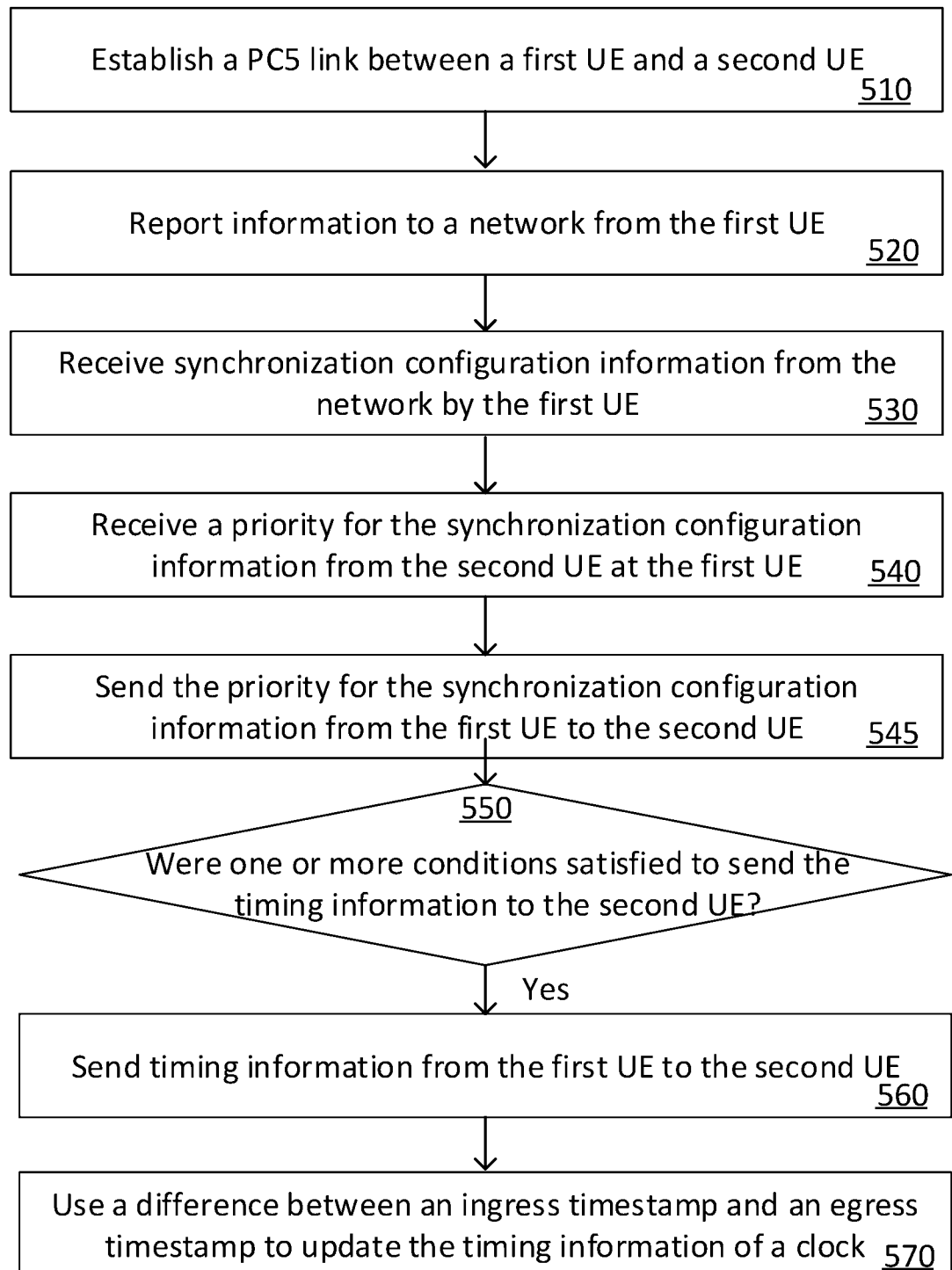
500

FIG. 5

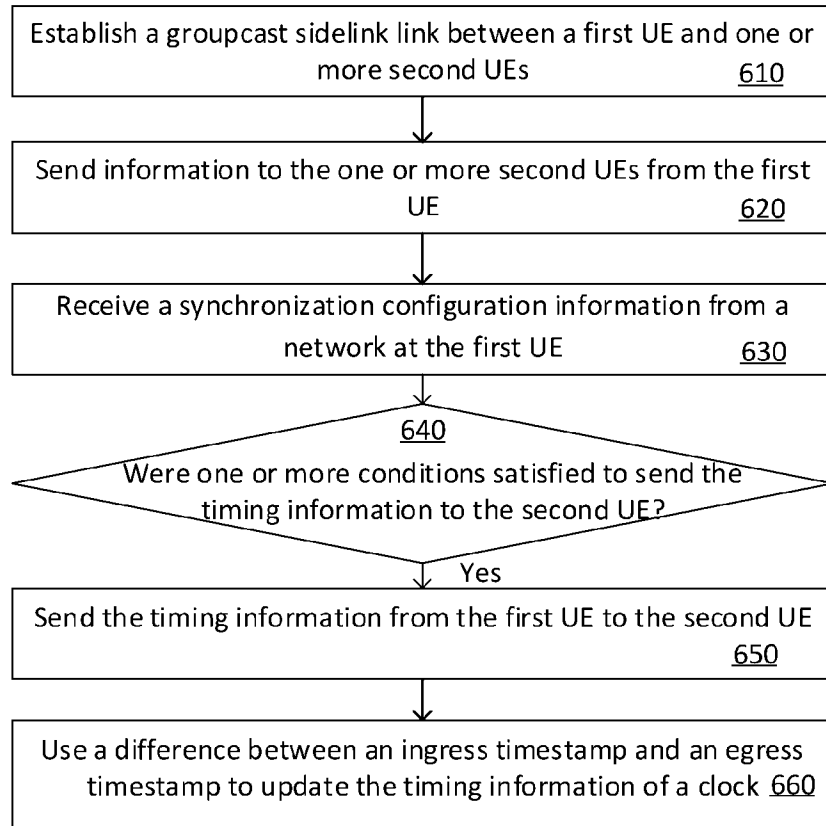
600

FIG. 6

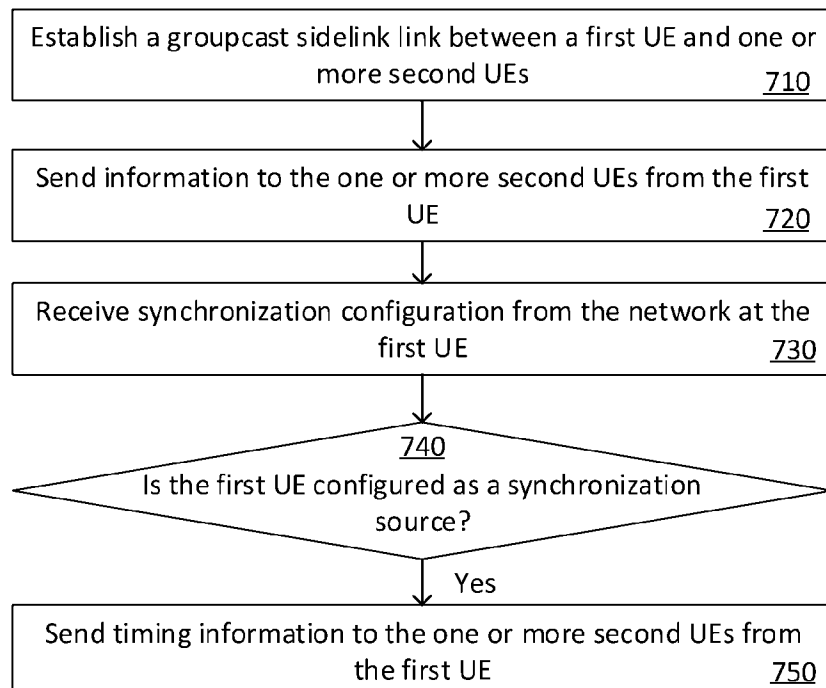
700

FIG. 7

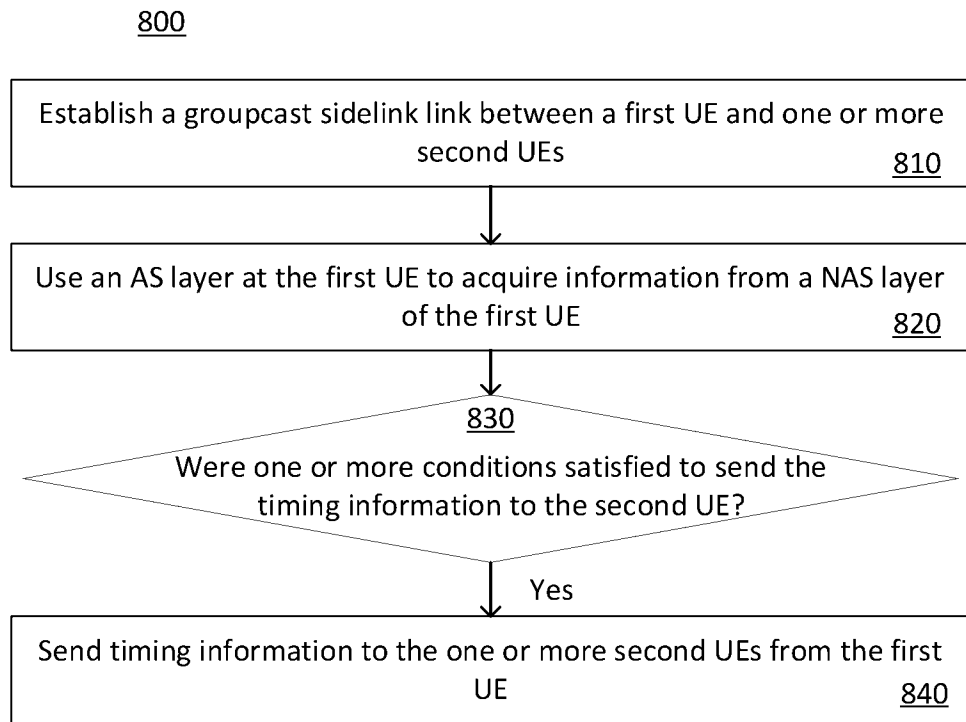


FIG. 8

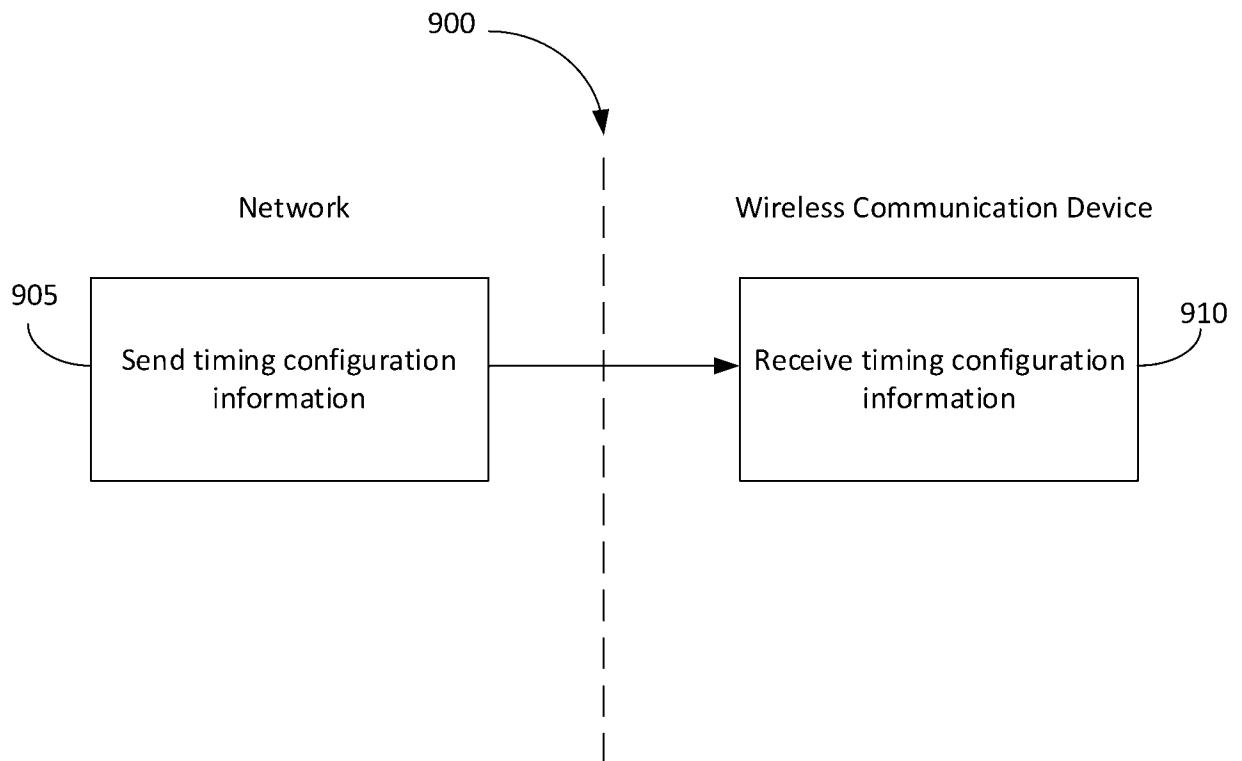


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2023/140748

A. CLASSIFICATION OF SUBJECT MATTER

H04W56/00(2009.01)i; H04W 8/14(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)

IPC: 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)

CNTXT, WPABS, ENTXT, ENTXTC, DWPI, VEN, 3GPP: SL, sidelink, synchronization, time, D2D, TSN, TSC, GNSS, network entity, priority, configuration, accuracy, capability

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023262624 A1 (NOKIA TECHNOLOGIES OY) 17 August 2023 (2023-08-17) description, paragraphs [0029]-[0051],[0060]-[0071], claims 17-38,figure 2	1-23
X	US 2020396599 A1 (QUALCOMM INCORPORATED) 17 December 2020 (2020-12-17) description, paragraphs [0060]-[0073]	1,15,21-23
A	CN 110447293 A (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 12 November 2019 (2019-11-12) the whole document	1-23
A	INTEL CORPORATION. "Sidelink Synchronization Design for NR V2X Communication" 3GPP TSG RAN WG1 Meeting #96bis R1-1904297, 12 April 2019 (2019-04-12), the whole document	1-23
A	WO 2018143854 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 09 August 2018 (2018-08-09) the whole document	1-23



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

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

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“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

09 September 2024

Date of mailing of the international search report

13 September 2024

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2023/140748

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2023262624	A1	17 August 2023	EP	4228343	A1	16 August 2023
US	2020396599	A1	17 December 2020	WO	2020252417	A1	17 December 2020
				EP	4307738	A2	17 January 2024
				EP	3984321	A1	20 April 2022
				CN	113924792	A	11 January 2022
				CN	118473626	A	09 August 2024
CN	110447293	A	12 November 2019	WO	2018174779	A1	27 September 2018
				US	2019289627	A1	19 September 2019
				EP	3603284	A1	05 February 2020
WO	2018143854	A1	09 August 2018	None			