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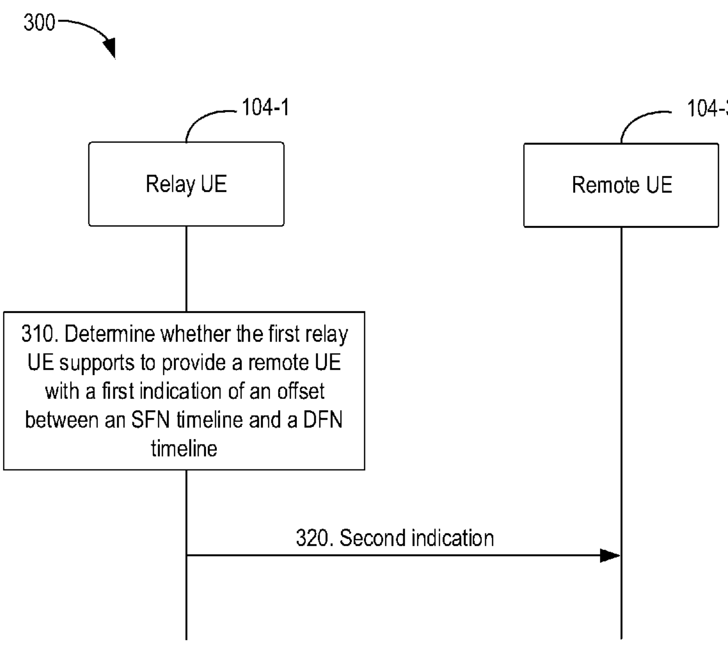

Fig. 3

(57) Abstract: Various aspects of the present disclosure relate to alignment in a multi-hop sidelink relay scenario. In one aspect, a first relay UE determines whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline. In turn, the first relay UE transmits a second indication to the remote UE based on the determination. The remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

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ALIGNMENT IN A MULTI-HOP SIDELINK RELAY SCENARIO

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to user equipment (UE), base station and methods for supporting alignment in a multi-hop sidelink (SL) relay scenario.

BACKGROUND

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

[0003] The third generation partnership project (3GPP) discussed to do new radio (NR) SL multi-hop relay work in Release 19 and suggested to start the work with specifying one additional hop relay.

[0004] In a multi-hop sidelink relay scenario, a remote user equipment (UE) may be to be connected to or may be connected to a network entity via a first relay UE and a second relay UE. The two relay UEs may be to be connected to or may be connected to each other via a PC-5 interface. One of the first relay UE and the second relay UE which is connected to the network entity directly may be referred to as a parent relay UE, and the other which is connected to the network entity via the parent relay UE may be referred to as a child relay UE.

SUMMARY

[0005] The present disclosure relates to UEs and methods that support alignment in a multi-hop sidelink relay scenario. With the present disclosure, a relay UE can indicate a remote UE whether the relay UE supports to provide an indication of an offset between a system frame number (SFN) timeline and a direct frame number (DFN) timeline.

[0006] Some implementations of a first relay UE described herein may include a processor and a transceiver coupled to the processor. The processor is configured to: determine whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline; and transmit a second indication via the transceiver to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0007] In some implementations, the processor is configured to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset based on at least one of the following: a first capability of the first relay UE for supporting to provide the first indication of the offset; or a second capability of the second relay UE for supporting to provide the first indication of the offset; or an indication from the network entity or the second relay UE.

[0008] In some implementations, the first capability of the first relay UE is that the first relay UE does not support to provide the first indication of the offset, the second capability of the second relay UE indicates that the second relay UE supports to provide the second indication of the offset. In such implementations, the processor is configured to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset based on the first capability and the second capability by: determining that the first relay UE supports to provide the remote UE with the first indication of the offset.

[0009] In some implementations, the processor is further configured to: transmit, via the transceiver to the remote UE, the first capability of the first relay UE; or transmit, via the transceiver to the remote UE, the first capability of the first relay UE and the second capability of the second relay UE.

[0010] In some implementations, the processor is further configured to: receive a request for the offset via the transceiver from the remote UE. The request for the offset is targeted to the second relay UE; and transmit the request for the offset via the transceiver to the second relay UE.

[0011] In some implementations, the first relay UE is out of coverage of the network entity. In such implementations, the first capability of the first relay UE indicates that the first relay UE supports to provide the first indication of the offset, the second capability of the second relay UE indicates that the second relay UE does not support to provide the second indication of the offset. In such implementations, the processor is further configured to: determine that the first relay UE cannot provide the remote UE with the first indication of the offset currently.

[0012] In some implementations, the processor is further configured to: transmit a third indication via the transceiver to the remote UE. The third indication indicates that the first relay UE cannot provide the remote UE with the first indication of the offset currently.

[0013] In some implementations, the processor is further configured to: transmit the first capability of the first relay UE via the transceiver to the remote UE.

[0014] In some implementations, the processor is configured to transmit the first capability of the first relay UE by: based on determining that the first relay UE supports to provide the remote UE with the first indication of the offset, transmitting the first capability of the first relay UE via the transceiver to the remote UE.

[0015] In some implementations, the processor is further configured to: transmit the second indication via the transceiver to the second relay UE.

[0016] In some implementations, the processor is further configured to: transmit, via the transceiver to the second relay UE, a first capability of the first relay UE for supporting to provide the first indication of the offset.

[0017] In some implementations, the processor is further configured to: based on determining that the first relay UE supports to provide the remote UE with the first indication of the offset, set a sidelink parameter to “supported”.

[0018] In some implementations, the processor is further configured to: based on determining that the first relay UE does not support to provide the remote UE with the first indication of the offset, set a sidelink parameter to “not supported”.

[0019] In some implementations, the processor is configured to transmit the second indication by: transmitting, via the transceiver to the remote UE, a message comprising the sidelink parameter.

[0020] In some implementations, the processor is configured to transmit the second indication by: based on determining that the first relay UE does not support to provide the remote UE with the first indication of the offset, transmitting a message without a sidelink parameter via the transceiver to the remote UE. In such implementations, absence of the sidelink parameter indicates the first relay UE does not support to provide the remote UE with the first indication of the offset.

[0021] In some implementations, the processor is further configured to: transmit, via the transceiver to the second relay UE, a request for the offset based on at least one of the following: a first sidelink being established between the first relay UE and the second relay UE; and a second sidelink being established between the first relay UE and the remote UE.

[0022] In some implementations, the processor is further configured to: receive, via the transceiver from the remote UE, a first request for the offset; and transmit, via the transceiver to the second relay UE, a second request for the offset based on the first request.

[0023] In some implementations, the processor is further configured to: upon transmitting the second indication to the remote UE, transmit a request for the offset via the transceiver to the second relay UE. The second indication indicates that the first relay UE supports to provide the remote UE with the first indication of the offset.

[0024] In some implementations, the processor is configured to transmit the request for the offset by: transmitting a dedicated message comprising the request for the offset; or transmitting a message comprising a dedicated information element (IE). The dedicated IE comprises the request for the offset.

[0025] In some implementations, the processor is further configured to: receive a first value of the offset via the transceiver from the second relay UE; determine a second value of the offset; and based on determining that the first value is different from the second value, transmit a fourth indication via the transceiver to the second relay UE or the network entity. The fourth indication indicates that the first value is different from the second value.

[0026] In some implementations, the processor is further configured to: receive a first value of the offset via the transceiver from the second relay UE; and transmit, via the transceiver to the remote UE, the first indication of the first value.

[0027] In some implementations, the processor is further configured to: determine a second value of the offset; and transmit, via the transceiver to the remote UE, the first indication of the second value.

[0028] In some implementations, the processor is configured to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset by: receiving a fifth indication via the transceiver from the network entity, wherein the fifth indication indicates to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset based on a first capability of the first relay UE for supporting to provide the first indication of the offset or based on a second capability of the second relay UE for supporting to provide the first indication of the offset; and determining whether the first relay UE supports to provide the remote UE with the first indication of the offset based on the fifth indication.

[0029] Some implementations of a remote UE described herein may include a processor and a transceiver coupled to the processor. The processor is configured to: receive a second indication via the transceiver from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0030] In some implementations, the processor is further configured to: transmit a request for the offset via the transceiver to the first relay UE.

[0031] In some implementations, the request for the offset is targeted to the second relay UE.

[0032] Some implementations of a method described herein may include: determining whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline; and transmitting a second indication to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0033] Some implementations of a method described herein may include: receiving a second indication from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0034] Some implementations of a processor described herein may include at least one memory and a controller coupled with the at least one memory and configured to cause the controller to: determine whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline; and transmit a second indication via the transceiver to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0035] Some implementations of a processor described herein may include at least one memory and a controller coupled with the at least one memory and configured to cause the controller to: receive a second indication from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0036] It is to be understood that the summary section is not intended to identify key or essential features of embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Fig. 1A illustrates an example of a wireless communications system that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure;

[0038] Fig. 1B illustrates another example of a wireless communications system that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure;

[0039] Fig. 2 illustrates an example of a potential control plane (CP) protocol stack for 2-hop L2 U2N relay architecture in accordance with aspects of the present disclosure;

[0040] Fig. 3 illustrates a flowchart of a method that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure;

[0041] Fig. 4 illustrates an example of a device that supports alignment in a multi-hop sidelink relay scenario in accordance with some aspects of the present disclosure;

[0042] Fig. 5 illustrates an example of a processor that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure; and

[0043] Figs. 6 and 7 illustrate a flowchart of a method that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure, respectively.

DETAILED DESCRIPTION

[0044] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein may be implemented in various manners other than the ones described below.

[0045] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0046] References in the present disclosure to "one embodiment," "an example embodiment," "an embodiment," "some embodiments," and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0047] It shall be understood that although the terms "first" and "second" or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

[0048] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0049] As described above, in a multi-hop sidelink relay scenario, a remote UE may be to be connected to or may be connected to a network entity via a first relay UE and a second relay UE.

[0050] When a UE is in coverage of a network entity, it can, for example, use information derived from the serving public land mobile network (PLMN). When the UE is not in coverage of the network entity, it can use other techniques, such as global navigation satellite system (GNSS). The layer 2 (L2) UE-to-Network (U2N) remote UE in RRC_IDLE/RRC_INACTIVE or RRC_CONNECTED can request an offset between an SFN timeline and a DFN timeline from the connected L2 U2N Relay UE if the U2N remote UE needs the offset based on a request from upper layers of the U2N remote UE and the connected L2 U2N relay UE supports to provide the offset.

[0051] Considering the multi-hop sidelink relay scenario, the capability for supporting to provide the offset may be different for a child relay UE and a parent relay UE. How to indicate the capability for supporting to provide the offset to the remote UE has not been discussed yet.

[0052] In view of the above, the present disclosure provides a solution that supports alignment in a multi-hop sidelink relay scenario. According to this solution, a first relay UE determines whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline. In turn, the first relay UE transmits a second indication to the remote UE based on the determination. The remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE. With this solution, the first relay UE can indicate the remote UE whether the first relay UE supports to provide the first indication of the offset.

[0053] Aspects of the present disclosure are described in the context of a wireless communications system.

[0054] Fig. 1 illustrates an example of a wireless communications system 100 that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The wireless communications system 100 may include one at least one of network entities 102 (also referred to as network equipment (NE)), one or more terminal devices or UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including institute of electrical and electronics engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0055] The network entities 102 may be collectively referred to as network entities 102 or individually referred to as a network entity 102. Hereinafter, some implementations of the present discourse will be described by taking a gNB as an example of the network entity 102. Thus, the network entity 102 is also referred to as a gNB 102.

[0056] The network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station (BS), a network element, a radio access network (RAN) node, a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0057] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0058] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an internet-of-things (IoT) device, an internet-of-everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0059] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in Fig. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in Fig. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0060] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0061] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0062] In some implementations, the network entity 102 may be implemented as a satellite. For example, the network entity 102-1 may be implemented as a satellite. Thus, network entity 102-1 is also referred to as a satellite 102-1. The network entity 102-1 may have full or part of an eNB/gNB on board. The communication link 110 between the satellite 102-1 and the UE 104, the communication link 116 between the satellite 102-1 and the network entity 102, and the communication link 116 between the satellite 102-1 and the core network 106 may be used for a non-terrestrial network (NTN) transparent mode. The communication link 110 between the satellite 102-1 and the UE 104, and the communication link 116 between the satellite 102-1 (with a base station on board) and the core network 106 may be used for a NTN regenerative mode.

[0063] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open radio access network (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN intelligent controller (RIC) (e.g., a near-real time RIC (Near-RT RIC), a non-real time RIC (Non-RT RIC)), a service management and orchestration (SMO) system, or any combination thereof.

[0064] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0065] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., radio resource control (RRC), service data adaption protocol (SDAP), packet data convergence protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0066] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0067] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0068] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a packet data network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0069] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0070] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities

102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0071] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0072] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0073] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0074] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (510 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0075] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0076] Fig. 1B illustrates an example of a wireless communications system 100B that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The wireless communications system 100B may be considered as an example implementation of the wireless communications system 100A.

[0077] As shown in Fig. 1B, the wireless communications system 100B may comprise the network entity 102, relay UEs 104-1, 104-2 and 104-6, as well as remote UEs 104-3, 104-4, 104-5 and 104-7.

[0078] The relay UE 104-2 may be connected to the network entity 102 directly. Thus, the relay UE 104-2 may be referred to as a parent relay UE 104-2.

[0079] The relay UE 104-1 may be connected to the remote UE 104-3 and the remote UE 104-4. The relay UE 104-6 may be connected to the remote UE 104-7. Each of the relay UE 104-1 and the relay UE 104-6 may be connected to the network entity 102 via the relay UE 104-2. Thus, the relay UE 104-1 may be referred to as a child relay UE 104-1, and the relay UE 104-6 may be referred to as a child relay UE 104-6. As shown in Fig. 1B, the relay UE 104-1 may be out of coverage of the network entity 102, and the relay UE 104-6 may be in coverage (IC) of the network entity 102.

[0080] Each of the remote UE 104-3 and the remote UE 104-4 may be to be connected to or may be connected to the network entity 102 via the relay UE 104-1 and the relay UE 104-2. The remote UE 104-7 may be to be connected to or may be connected to the network entity 102 via the relay UE 104-6 and the relay UE 104-2. The remote UE 104-5 may be to be connected to or may be connected to the network entity 102 via the relay UE 104-2.

[0081] It shall be noted that although the relay UE 104-1 is shown to be out of coverage of the network entity 102 in Fig. 1B, the relay UE 104-1 may be in coverage of the network entity 102 in other implementations.

[0082] Fig. 2 illustrates an example of a potential control plane (CP) protocol stack for 2-hop L2 U2N relay architecture in accordance with aspects of the present disclosure. As shown in Fig. 2, the SRAP sublayer is placed above the RLC sublayer at both PC5 interface and Uu interface. The Uu SRAP, PDCP and RRC are terminated between L2 U2N Remote UE and gNB, while SRAP, RLC, MAC and PHY are terminated in each hop (i.e., the link between L2 U2N Remote UE and the L2 U2N Relay UE, the link between the two L2 U2N Relay UEs, and the link between L2 U2N Relay UE and the gNB).

[0083] In some implementations, for L2 U2N Relay, for uplink, the Uu SRAP sublayer performs UL bearer mapping between end-to-end Uu Radio Bearers of L2 U2N remote UE (identified for the purposes of this mapping by the local Remote UE ID and an associated bearer ID) and egress Uu Relay RLC channels over the L2 U2N Relay UE

Uu interface. For uplink relaying traffic, the different end-to-end Uu Radio Bearers (SRBs or DRBs) of the same L2 U2N Remote UE and/or different L2 U2N Remote UEs can be multiplexed over the same egress Uu Relay RLC channel. The Uu SRAP sublayer supports L2 U2N Remote UE identification for the UL traffic. The identity information of L2 U2N Remote UE end-to-end Uu Radio Bearer and a local Remote UE ID are included in the Uu SRAP header at UL in order for gNB to correlate the received packets for the specific PDCP entity associated with the right end-to-end Uu Radio Bearer of the L2 U2N Remote UE. The PC5 SRAP sublayer at the L2 U2N Remote UE supports UL bearer mapping between L2 U2N Remote UE end-to-end Uu Radio Bearers and egress PC5 Relay RLC channels.

[0084] In some implementations, for L2 U2N Relay, for downlink, the Uu SRAP sublayer performs DL bearer mapping at gNB to map end-to-end Uu Radio Bearer (SRB, DRB) of L2 U2N Remote UE (identified for the purposes of this mapping by the local Remote UE ID and an associated bearer ID) into Uu Relay RLC channel. The Uu SRAP sublayer performs DL bearer mapping and data multiplexing between multiple end-to-end Radio Bearers (SRBs or DRBs) of a L2 U2N Remote UE and/or different L2 U2N Remote UEs and one Uu Relay RLC channel over the L2 U2N Relay UE Uu interface. The Uu SRAP sublayer supports L2 U2N Remote UE identification for DL traffic. The identity information of L2 U2N Remote UE end-to-end Uu Radio Bearer and a local Remote UE ID are included into the Uu SRAP header by the gNB at DL for the L2 U2N Relay UE to identify the corresponding end-to-end Uu Radio Bearer(s) of L2 U2N Remote UE. The PC5 SRAP sublayer at the L2 U2N Relay UE performs DL bearer mapping between end-to-end Uu Radio Bearers of L2 U2N remote UE and egress PC5 Relay RLC channels. The PC5 SRAP sublayer at the L2 U2N Remote UE correlates the received packets with the right PDCP entity associated with the given end-to-end Uu Radio Bearer of the L2 U2N Remote UE based on the identity information included in the PC5 SRAP header.

[0085] In some implementations, a local Remote UE ID may be included in both PC5 SRAP header and Uu SRAP header. Alternatively, the local Remote UE ID may be included in PC5 SRAP header. L2 U2N Relay UE is configured by the gNB with the local Remote UE ID(s) to be used in SRAP header. L2 U2N Remote UE obtains the local Remote ID from the gNB via Uu RRC messages including RRCSetup, RRCReconfiguration, RRCResume and RRCReestablishment.

[0086] In some implementations, the end-to-end DRB(s) or end-to-end SRB(s), except SRB0, of L2 U2N Remote UE can be multiplexed to the PC5 Relay RLC channels and Uu Relay RLC channels in both PC5 hop and Uu hop.

[0087] In some implementations, it is the gNB responsibility to avoid collision on the usage of local Remote UE ID. The gNB can update the local Remote UE ID by sending the updated local Remote UE ID via RRCReconfiguration message. The serving gNB can perform local Remote UE ID update independent of the PC5 unicast link L2 ID update procedure.

[0088] Hereinafter, some implementations of the present disclosure will be described with reference to Figs. 3 to 7.

[0089] Fig. 3 illustrates a signaling chart illustrating an example process 300 that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The process 300 may involve a first relay UE, a second relay UE and a remote UE.

[0090] In some implementations, the first relay UE may be implemented as the relay UE 104-1. In such implementations, the second relay UE may be implemented as the relay UE 104-2, and the remote UE may be implemented as the remote UE 104-3 or 104-4.

[0091] Alternatively, in some implementations, the first relay UE may be implemented as the relay UE 104-6. In such implementations, the second relay UE may be implemented as the relay UE 104-2, and the remote UE may be implemented as the UE 104-7.

[0092] For the purpose of discussion, the process 300 will be described with reference to Fig. 1B by taking the relay UE 104-1 as an example of the first relay UE, the relay UE 104-2 as an example of the second relay UE, and the UE 104-3 as an example of the remote UE.

[0093] As shown in Fig. 3, the relay UE 104-1 determines 310 whether the relay UE 104-1 supports to provide the remote UE 104-3 with a first indication of an offset between an SFN timeline and a DFN timeline. Hereinafter, for brevity, an offset between an SFN timeline and a DFN timeline is also referred to as an SFN-DFN offset.

[0094] In turn, the relay UE 104-1 transmits 320 a second indication to the remote UE 104-3 based on the determination. The remote UE 104-3 is to be connected to or is connected to the network entity 102 via the relay UE 104-1 and a relay UE 104-2.

[0095] In some implementations, if the relay UE 104-1 determines that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the second indication indicates the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset. On the other hand, if the relay UE 104-1 determines that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the second indication indicates the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0096] With the process 300, the relay UE 104-1 can indicate the remote UE 104-3 whether the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset.

[0097] In some implementations, the relay UE 104-1 may determine whether the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset based on at least one of the following: a first capability of the relay UE 104-1 for supporting to provide the first indication of the offset, or a second capability of the relay UE 104-2 for supporting to provide the first indication of the offset, or an indication from the network entity 102 or the second relay UE 104-2.

[0098] In some implementations, the relay UE 104-1 may obtain the second capability of the relay UE 104-2 from the relay UE 104-2.

[0099] Consider a first implementation. In the first implementation, the relay UE 104-1 may be in coverage or out of coverage of the network entity 102.

[0100] In the first implementation, the first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 supports to provide the second indication of the offset. In such an implementation, the relay UE 104-1 may determine that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0101] In the first implementation, if the relay UE 104-1 determines that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "supported". In such implementations, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter.

[0102] For example, the message may comprise a *UECapabilityInformationSidelink* message and the sidelink parameter may comprise "sfn-DFN-OffsetSupported-r18". The

UECapabilityInformationSidelink message may comprise "UECapabilityInformationSidelink-v1800-IEs" as below:

UECapabilityInformationSidelink-v1800-IEs ::= SEQUENCE {

sfn-DFN-OffsetSupported-r18 ENUMERATED { supported } OPTIONAL

...

where a value of "sfn-DFN-OffsetSupported-r18" set to "supported" indicates that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0103] Alternatively, if the relay UE 104-1 determines that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message without the sidelink parameter. Absence of the sidelink parameter from the message indicates the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0104] Alternatively or additionally, the relay UE 104-1 may transmit the second indication to the relay UE 104-2.

[0105] In the first implementation, the relay UE 104-1 may obtain the SFN-DFN offset from the relay UE 104-2. In such an implementation, the relay UE 104-1 may transmit a request for the SFN-DFN offset to the relay UE 104-2. In turn, the relay UE 104-1 may receive a response from the relay UE 104-2. The response may comprise the SFN-DFN offset.

[0106] In the first implementation, if a first sidelink is established between the relay UE 104-1 and the relay UE 104-2, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0107] Alternatively or additionally, if a second sidelink is established between the relay UE 104-1 and the remote UE 104-3, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0108] Alternatively, if the first sidelink is established between the relay UE 104-1 and the relay UE 104-2 and a second sidelink is established between the relay UE 104-1 and the remote UE 104-3, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0109] Alternatively, the relay UE 104-1 may receive, from the remote UE 104-3, a first request for the SFN-DFN offset. In turn, the relay UE 104-1 may transmit, to the relay UE 104-2, a second request for the SFN-DFN offset based on the first request.

[0110] Alternatively, upon transmitting to the remote UE 104-3 the second indication indicating that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0111] Consider a second implementation. In the second implementation, the relay UE 104-1 may be in coverage or out of coverage of the network entity 102.

[0112] In the second implementation, the first capability of the relay UE 104-1 is that the relay UE 104-1 does not support to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 supports to provide the second indication of the offset. In such implementations, the relay UE 104-1 may determine that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0113] In the second implementation, the relay UE 104-1 may transmit the first capability of the relay UE 104-1 to the remote UE 104-3. Alternatively, the relay UE 104-1 may transmit, to the remote UE 104-3, the first capability of the relay UE 104-1 and the second capability of the relay UE 104-2.

[0114] In the second implementation, the relay UE 104-1 may inform the relay UE 104-2 that the first capability of the relay UE 104-1 is that the relay UE 104-1 does not support to provide the first indication of the offset. The relay UE 104-1 may also inform the relay UE 104-2 that the relay UE 104-1 transmits, to the remote UE 104-3, the second indication indicating that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset.

[0115] In the second implementation, the relay UE 104-1 may obtain the SFN-DFN offset from the relay UE 104-2. In such an implementation, the relay UE 104-1 may transmit a request for the SFN-DFN offset to the relay UE 104-2. In turn, the relay UE 104-1 may receive a response from the relay UE 104-2. The response may comprise the SFN-DFN offset.

[0116] In the second implementation, if a first sidelink is established between the relay UE 104-1 and the relay UE 104-2, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0117] Alternatively or additionally, if a second sidelink is established between the relay UE 104-1 and the remote UE 104-3, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0118] Alternatively, if the first sidelink is established between the relay UE 104-1 and the relay UE 104-2 and a second sidelink is established between the relay UE 104-1 and the remote UE 104-3, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0119] Alternatively, the relay UE 104-1 may receive, from the remote UE 104-3, a first request for the SFN-DFN offset. In turn, the relay UE 104-1 may transmit, to the relay UE 104-2, a second request for the SFN-DFN offset based on the first request.

[0120] For example, the first request for the SFN-DFN offset received from the remote UE 104-3 may be targeted to the relay UE 104-2. The relay UE 104-1 may forward the first request to the relay UE 104-2.

[0121] For example, the relay UE 104-1 may receive, from the remote UE 104-3, a *RemoteUEInformationSidelink message* comprising the first request for the SFN-DFN offset. Alternatively, the relay UE 104-1 may receive, from the remote UE 104-3, a dedicated message or a dedicated IE comprising the first request for the SFN-DFN offset.

[0122] Alternatively, upon transmitting to the remote UE 104-3 the second indication indicating that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset, the relay UE 104-1 may transmit the request for the SFN-DFN offset to the relay UE 104-2.

[0123] In the second implementation, the relay UE 104-1 may transmit, to the relay UE 104-2, a dedicated message or a dedicated IE comprising the request for the SFN-DFN offset.

[0124] In the second implementation, if the relay UE 104-1 determines that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "not supported". In such an implementation, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter.

[0125] For example, the message may comprise a *UECapabilityInformationSidelink* message and the sidelink parameter may comprise "sfn-DFN-OffsetSupported-r18". The *UECapabilityInformationSidelink* message may comprise "UECapabilityInformationSidelink-v1800-IEs" as below:

UECapabilityInformationSidelink-v1800-IEs ::= SEQUENCE {

sfn-DFN-OffsetSupported-r18 ENUMERATED { not supported } OPTIONAL

...

where a value of "sfn-DFN-OffsetSupported-r18" set to "not supported" indicates that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset. It shall be noted that the sidelink parameter is described by taking "sfn-DFN-OffsetSupported-r18" for example. The sidelink parameter may be named differently. The scope of the present disclosure is not limited in this regard.

[0126] For another example, the message may comprise a dedicated message or a dedicated IE comprising the sidelink parameter.

[0127] Alternatively, in the second implementation, if the relay UE 104-1 determines that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may not set a sidelink parameter to "not supported". In such an implementation, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message without the sidelink parameter. Absence of the sidelink parameter from the message indicates the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0128] For example, the message may comprise a *UECapabilityInformationSidelink* message. The *UECapabilityInformationSidelink* message may comprise "UECapabilityInformationSidelink-v1800-IEs" which does not comprise "sfn-DFN-OffsetSupported-r18". Absence of "sfn-DFN-OffsetSupported-r18" from the "UECapabilityInformationSidelink-v1800-IEs" indicates the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0129] Consider a third implementation. In the third implementation, the relay UE 104-1 is out of coverage of the network entity 102.

[0130] In the third implementation, the first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 does not support to provide the second indication of the offset. In such implementations, the relay UE 104-1 may determine that the relay UE 104-1 cannot provide the remote UE 104-3 with the first indication of the SFN-DFN offset currently.

[0131] In the third implementation, the relay UE 104-1 may transmit a third indication to the remote UE 104-3. The third indication indicates that the relay UE 104-1 cannot provide the remote UE 104-3 with the first indication of the SFN-DFN offset or the relay UE 104-1 cannot provide the remote UE 104-3 with the first indication of the SFN-DFN offset currently.

[0132] In the third implementation, the relay UE 104-1 may transmit the third indication to the remote UE 104-3 via a dedicated or new capability. Alternatively, the relay UE 104-2 may transmit the third indication to the remote UE 104-3 via a capability indication and an able/unable indication.

[0133] In the third implementation, if the relay UE 104-1 determines that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset, the relay UE 104-1 may transmit the first capability of the relay UE 104-1 to the remote UE 104-3. The first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset.

[0134] Alternatively, if the relay UE 104-1 determines that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset, the relay UE 104-1 may transmit the second indication to the remote UE 104-3. The second indication indicates that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset, or the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset but currently the value of the SFN-DFN offset cannot be provided.

[0135] For example, if the relay UE 104-1 moves to coverage of the network entity 102, the relay UE 104-1 may determine that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset. Then, the relay UE 104-1 may transmit the first capability of the relay UE 104-1 or the second indication to the remote UE 104-3.

[0136] If the relay UE 104-1 determines that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "supported". In such implementations, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter. If the relay UE 104-1 determines that the relay UE 104-1 supports but cannot currently provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "supported once in coverage (IC)". In such implementations, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter.

[0137] For example, the message may comprise a *UECapabilityInformationSidelink* message and the sidelink parameter may comprise "sfn-DFN-OffsetSupported-r18". The *UECapabilityInformationSidelink* message may comprise "UECapabilityInformationSidelink-v1800-IEs" as below:

UECapabilityInformationSidelink-v1800-IEs ::= SEQUENCE {

sfn-DFN-OffsetSupported-r18 ENUMERATED { supported, supported once IC } OPTIONAL

...

where a value of "sfn-DFN-OffsetSupported-r18" set to "supported" indicates that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0138] Upon receiving the second indication indicating that the relay UE 104-1 supports to provide the first indication of the SFN-DFN offset, the remote UE 104-3 may transmit a request for the SFN-DFN offset to the relay UE 104-1. Then, the relay UE 104-1 will provide the first indication of the SFN-DFN offset.

[0139] Consider a fourth implementation. In the fourth implementation, the relay UE 104-1 is out of coverage of the network entity 102. The first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 does not support to provide the second indication of the offset. In such implementations, the relay UE 104-1 may determine that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0140] In the fourth implementation, if the relay UE 104-1 determines that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "not supported". In such an implementation, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter.

[0141] For example, the message may comprise a *UECapabilityInformationSidelink* message and the sidelink parameter may comprise "sfn-DFN-OffsetSupported-r18". The *UECapabilityInformationSidelink* message may comprise "UECapabilityInformationSidelink-v1800-IEs" as below:

UECapabilityInformationSidelink-v1800-IEs ::= SEQUENCE {

sfn-DFN-OffsetSupported-r18 ENUMERATED { not supported, supported, supported once IC } OPTIONAL

...

where a value of "sfn-DFN-OffsetSupported-r18" set to "not supported" indicates that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0142] For another example, the message may comprise a dedicated message or a dedicated IE comprising the sidelink parameter.

[0143] Consider a fifth implementation. In the fifth implementation, the relay UE 104-1 is out of coverage of the network entity 102. The first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 does not support to provide the second indication of the offset. In such implementations, the relay UE 104-1 may determine that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0144] If the relay UE 104-1 determines that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "supported". In such implementations, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter.

[0145] For example, the message may comprise a *UECapabilityInformationSidelink* message and the sidelink parameter may comprise "sfn-DFN-OffsetSupported-r18". The *UECapabilityInformationSidelink* message may comprise "UECapabilityInformationSidelink-v1800-IEs" as below:

UECapabilityInformationSidelink-v1800-IEs ::= SEQUENCE {

sfn-DFN-OffsetSupported-r18 ENUMERATED { supported } OPTIONAL

...

where a value of "sfn-DFN-OffsetSupported-r18" set to "supported" indicates that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0146] Consider a sixth implementation. In the sixth implementation, the relay UE 104-1 may be in coverage of the network entity 102.

[0147] In the sixth implementation, the first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 does not support to provide the second indication of the offset. In such implementations, the relay UE 104-1 may determine that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0148] In the sixth implementation, the relay UE 104-1 may obtain the SFN-DFN offset from the network entity 102 via the relay UE 104-2. In such an implementation, the relay UE 104-1 may transmit a request for the SFN-DFN offset to the relay UE 104-2. The request for the SFN-DFN offset is targeted to the network entity 102. For example, the relay UE 104-1 may transmit a *UuMessageTransferSidelink* message, a dedicated sidelink message or a dedicated IE comprising the request or comprising the request and the DFN or comprising the DFN which implicitly requests the offset. In turn, the relay UE 104-1 may receive a response from the relay UE 104-2. The response may comprise the SFN-DFN offset.

[0149] Alternatively, in the sixth implementation, the relay UE 104-1 may determine the SFN-DFN offset by itself.

[0150] For example, when the relay UE 104-1 selects GNSS as the synchronization reference source, the DFN, the subframe number within a frame and slot number within a frame used for NR sidelink communication/discovery are derived from the current UTC time, by the following formulae:

$$DFN = \text{Floor}\ (0.1*(Tcurrent - Tref - OffsetDFN))\ \text{mod}\ 1024$$

$$SubframeNumber = Floor\ (Tcurrent - Tref - OffsetDFN)\ mod\ 10$$

$$SlotNumber = Floor\ ((Tcurrent - Tref - OffsetDFN)*2\mu)\ mod\ (10*2\mu)$$

Where:

Tcurrent is the current UTC time obtained from GNSS. This value is expressed in milliseconds;

Tref is the reference UTC time 00:00:00 on Gregorian calendar date 1 January, 1900 (midnight between Thursday, December 31, 1899 and Friday, January 1, 1900). This value is expressed in milliseconds;

OffsetDFN is the value *sl-OffsetDFN* if configured, otherwise it is zero. This value is expressed in milliseconds.

μ=0/1/2/3 corresponding to the 15/30/60/120 kHz of SCS for SL, respectively.

[0151] In the sixth implementation, if the relay UE 104-1 determines the SFN-DFN offset by itself, the relay UE 104-1 may transmit the SFN-DFN offset to the relay UE 104-2 once a first sidelink is established between the relay UE 104-1 and the relay UE 104-2.

[0152] In the sixth implementation, if the relay UE 104-1 determines that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset, the relay UE 104-1 may set a sidelink parameter to "supported". In such implementations, the relay UE 104-1 may transmit the second indication by transmitting, to the remote UE 104-3, a message comprising the sidelink parameter.

[0153] For example, the message may comprise a *UECapabilityInformationSidelink* message and the sidelink parameter may comprise "sfn-DFN-OffsetSupported-r18". The *UECapabilityInformationSidelink* message may comprise "UECapabilityInformationSidelink-v1800-IEs" as below:

UECapabilityInformationSidelink-v1800-IEs ::= SEQUENCE {

sfn-DFN-OffsetSupported-r18 ENUMERATED { supported } OPTIONAL

...

where a value of "sfn-DFN-OffsetSupported-r18" set to "supported" indicates that the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0154] Consider a seventh implementation. In the seventh implementation, the relay UE 104-1 may be in coverage of the network entity 102.

[0155] In the seventh implementation, the first capability of the relay UE 104-1 is that the relay UE 104-1 supports to provide the first indication of the offset, and the second capability of the relay UE 104-2 indicates that the relay UE 104-2 does not support to provide the second indication of the offset. In such implementations, the relay UE 104-1 may determine that the relay UE 104-1 does not support to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0156] In some implementations, the relay UE 104-1 may receive a first value of the SFN-DFN offset from the relay UE 104-2. The relay UE 104-1 may transmit, to the remote UE 104-3, the first indication of the first value.

[0157] In some implementations, the relay UE 104-1 may determine a second value of the SFN-DFN offset. For example, the relay UE 104-1 may determine a second value of the SFN-DFN offset from GNSS as described above in the sixth implementation. The relay UE 104-1 may transmit, to the remote UE 104-3, the first indication of the second value.

[0158] In some implementations, if the first value of the SFN-DFN offset is different from the second value of the SFN-DFN offset, it can be considered as an error case by the relay UE 104-1.

[0159] Alternatively or additionally, in some implementations, if the first value of the SFN-DFN offset is different from the second value of the SFN-DFN offset, the relay UE 104-1 may transmit a fourth indication to the relay UE 104-2 or the network entity 102. The fourth indication indicates that the first value is different from the second value.

[0160] In some implementations, the network entity 102 may indicate it is up to the relay UE 104-2 or the network entity 102 to determine whether the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset. In some implementations, the relay UE 104-1 may receive a fifth indication from the network entity 102. The fifth indication indicates to determine whether the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset based on a first capability of the relay UE 104-1 for supporting to provide the first indication of the SFN-DFN offset or based on a second capability of the relay UE 104-2 for supporting to provide the first indication of the SFN-DFN offset. In turn, the relay UE 104-1 may determine whether the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset based on the fifth indication.

[0161] In some implementations, if the first capability of the relay UE 104-1 for supporting to provide the first indication of the SFN-DFN offset is different from (or not aligned with) the second capability of the relay UE 104-2 for supporting to provide the first indication of the SFN-DFN offset, the network entity 102 may transmit the fifth indication to the relay UE 104-1.

[0162] Alternatively, it is predefined or it is a default configuration that it is up to the relay UE 104-2 or the network entity 102 to determine whether the relay UE 104-1 supports to provide the remote UE 104-3 with the first indication of the SFN-DFN offset.

[0163] Fig. 4 illustrates an example of a device 400 that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The device 400 may be an example of a network entity 102 or a UE 104 as described herein. The device 400 may support wireless communication with one or more network entities

102, UEs 104, or any combination thereof. The device 400 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 402, a memory 404, a transceiver 406, and, optionally, an I/O controller 408. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0164] The processor 402, the memory 404, the transceiver 406, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 402, the memory 404, the transceiver 406, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0165] In some implementations, the processor 402, the memory 404, the transceiver 406, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 402 and the memory 404 coupled with the processor 402 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 402, instructions stored in the memory 404).

[0166] For example, the processor 402 may support wireless communication at the device 400 in accordance with examples as disclosed herein. The processor 402 may be configured to operable to support a means for performing the following: determining whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline; and transmitting a second indication to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0167] Alternatively, in some implementations, the processor 402 may be configured to operable to support a means for performing the following: receiving a second indication from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0168] The processor 402 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 402 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 402. The processor 402 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 404) to cause the device 400 to perform various functions of the present disclosure.

[0169] The memory 404 may include random access memory (RAM) and read-only memory (ROM). The memory 404 may store computer-readable, computer-executable code including instructions that, when executed by the processor 402 cause the device 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 402 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 404 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0170] The I/O controller 408 may manage input and output signals for the device 400. The I/O controller 408 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 408 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 408 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 408 may be implemented as part of a processor, such as the processor 406. In some implementations, a user may interact with the device 400 via the I/O controller 408 or via hardware components controlled by the I/O controller 408.

[0171] In some implementations, the device 400 may include a single antenna 410. However, in some other implementations, the device 400 may have more than one antenna 410 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 406 may communicate bi-directionally, via the one or more antennas 410, wired, or wireless links as described herein. For example, the transceiver 406 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 406 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 410 for transmission, and to demodulate packets received from the one or more antennas 410. The transceiver 406 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0172] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 410 for transmitting the amplified signal into the air or wireless medium.

[0173] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 410 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0174] Fig. 5 illustrates an example of a processor 500 that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The processor 500 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 500 may include a controller 502 configured to perform various operations in accordance with examples as described herein. The processor 500 may optionally include at least one memory 504, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 500 may optionally include one or more arithmetic-logic units (ALUs) 506. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0175] The processor 500 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 500) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0176] The controller 502 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 500 to cause the processor 500 to support various operations in accordance with examples as described herein. For example, the controller 502 may operate as a control unit of the processor 500, generating control signals that manage the operation of various components of the processor 500. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0177] The controller 502 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 504 and determine subsequent instruction(s) to be executed to cause the processor 500 to support various operations in accordance with examples as described herein. The controller 502 may be configured to track memory address of instructions associated with the memory 504. The controller 502 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 502 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 500 to cause the processor 500 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 502 may be configured to manage flow of data within the processor 500. The controller 502 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 500.

[0178] The memory 504 may include one or more caches (e.g., memory local to or included in the processor 500 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 504 may reside within or on a processor chipset (e.g., local to the processor 500). In some other implementations, the memory 504 may reside external to the processor chipset (e.g., remote to the processor 500).

[0179] The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 500, cause the processor 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 502 and/or the processor 500 may be configured to execute computer-readable instructions stored in the memory 504 to cause the processor 500 to perform various functions. For example, the processor 500 and/or the controller 502 may be coupled with or to the memory 504, the processor 500, the controller 502, and the memory 504 may be configured to perform various functions described herein. In some examples, the processor 500 may include multiple processors and the memory 504 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0180] The one or more ALUs 506 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 506 may reside within or on a processor chipset (e.g., the processor 500). In some other implementations, the one or more ALUs 506 may reside external to the processor chipset (e.g., the processor 500). One or more ALUs 506 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 506 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 506 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 506 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 506 to handle conditional operations, comparisons, and bitwise operations.

[0181] The processor 500 may support wireless communication at the device 400 in accordance with examples as disclosed herein. The processor 500 may be configured to operable to support a means for performing the following: determining whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline; and transmitting a second indication to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0182] Alternatively, in some implementations, the processor 500 may be configured to operable to support a means for performing the following: receiving a second indication from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

[0183] Fig. 6 illustrates a flowchart of a method 600 that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The operations of the method 600 may be implemented by a device or its components as described herein. For example, the operations of the method 600 may be performed by the relay UE 104-1 or 104-6 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0184] At 610, the method may include determining whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline. The operations of 610 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 610 may be performed by a device as described with reference to Fig. 1B.

[0185] At 620, the method may include transmitting a second indication to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE. The operations of 620 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 620 may be performed by a device as described with reference to Fig. 1B.

[0186] Fig. 7 illustrates a flowchart of a method 700 that supports alignment in a multi-hop sidelink relay scenario in accordance with aspects of the present disclosure. The operations of the method 700 may be implemented by a device or its components as described herein. For example, the operations of the method 700 may be performed by the remote UE 104-3, 104-4 or 104-7 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0187] At 710, the method may include receiving a second indication from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE. The operations of 710 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 710 may be performed by a device as described with reference to Fig. 1B.

[0188] It shall be noted that implementations of the present disclosure which have been described with reference to Figs. 1A to 3 are also applicable to the device 400, the processor 500 as well as the methods 600 and 700.

[0189] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0190] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0191] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0192] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[0193] As used herein, including in the claims, an article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[0194] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

1. A first relay user equipment (UE), comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

determine whether the first relay UE supports to provide a remote UE with a first indication of an offset between a system frame number (SFN) timeline and a direct frame number (DFN) timeline; and

transmit a second indication via the transceiver to the remote UE based on the determination, wherein the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

2. The first relay UE of claim 1, wherein the processor is configured to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset based on at least one of the following:

a first capability of the first relay UE for supporting to provide the first indication of the offset; or

a second capability of the second relay UE for supporting to provide the first indication of the offset; or

an indication from the network entity or the second relay UE.

3. The first relay UE of claim 2, wherein the first capability of the first relay UE is that the first relay UE does not support to provide the first indication of the offset, the second capability of the second relay UE indicates that the second relay UE supports to provide the second indication of the offset; and

wherein the processor is configured to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset based on the first capability and the second capability by:

determining that the first relay UE supports to provide the remote UE with the first indication of the offset.

4. The first relay UE of claim 3, wherein the processor is further configured to:

transmit, via the transceiver to the remote UE, the first capability of the first relay UE; or

transmit, via the transceiver to the remote UE, the first capability of the first relay UE and the second capability of the second relay UE.

5. The first relay UE of claim 4, wherein the processor is further configured to:

receive a request for the offset via the transceiver from the remote UE, wherein the request for the offset is targeted to the second relay UE; and

transmit the request for the offset via the transceiver to the second relay UE.

6. The first relay UE of claim 2, wherein the first relay UE is out of coverage of the network entity;

wherein the first capability of the first relay UE indicates that the first relay UE supports to provide the first indication of the offset, the second capability of the second relay UE indicates that the second relay UE does not support to provide the second indication of the offset; and

wherein the processor is further configured to:

determine that the first relay UE cannot provide the remote UE with the first indication of the offset currently.

7. The first relay UE of claim 6, wherein the processor is further configured to:

transmit the first capability of the first relay UE via the transceiver to the remote UE.

8. The first relay UE of claim 1, wherein the processor is further configured to:

transmit the second indication via the transceiver to the second relay UE.

9. The first relay UE of claim 1, wherein the processor is further configured to:

based on determining that the first relay UE supports to provide the remote UE with the first indication of the offset, set a sidelink parameter to “supported”.

10. The first relay UE of claim 1, wherein the processor is further configured to:

based on determining that the first relay UE does not support to provide the remote UE with the first indication of the offset, set a sidelink parameter to "not supported".

11. The first relay UE of claim 1, wherein the processor is configured to transmit the second indication by:

based on determining that the first relay UE does not support to provide the remote UE with the first indication of the offset, transmitting a message without a sidelink parameter via the transceiver to the remote UE, wherein absence of the sidelink parameter indicates the first relay UE does not support to provide the remote UE with the first indication of the offset.

12. The first relay UE of claim 1, wherein the processor is further configured to:

transmit, via the transceiver to the second relay UE, a request for the offset based on at least one of the following:

a first sidelink being established between the first relay UE and the second relay UE; and

a second sidelink being established between the first relay UE and the remote UE.

13. The first relay UE of claim 1, wherein the processor is further configured to:

receive, via the transceiver from the remote UE, a first request for the offset; and

transmit, via the transceiver to the second relay UE, a second request for the offset based on the first request.

14. The first relay UE of claim 1, wherein the processor is further configured to:

upon transmitting the second indication to the remote UE, transmit a request for the offset via the transceiver to the second relay UE, wherein the second indication indicates that the first relay UE supports to provide the remote UE with the first indication of the offset.

15. The first relay UE of any of claims 12 to 14, wherein the processor is configured to transmit the request for the offset by:

transmitting a dedicated message comprising the request for the offset; or

transmitting a message comprising a dedicated information element (IE), wherein the dedicated IE comprises the request for the offset.

16. The first relay UE of claim 1, wherein the processor is further configured to:

receive a first value of the offset via the transceiver from the second relay UE;

determine a second value of the offset; and

based on determining that the first value is different from the second value, transmit a fourth indication via the transceiver to the second relay UE or the network entity, wherein the fourth indication indicates that the first value is different from the second value.

17. The first relay UE of claim 1, wherein the processor is further configured to:

receive a first value of the offset via the transceiver from the second relay UE; and

transmit, via the transceiver to the remote UE, the first indication of the first value.

18. The first relay UE of claim 1, wherein the processor is further configured to:

determine a second value of the offset; and

transmit, via the transceiver to the remote UE, the first indication of the second value.

19. The first relay UE of claim 1, wherein the processor is configured to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset by:

receiving a fifth indication via the transceiver from the network entity, wherein the fifth indication indicates to determine whether the first relay UE supports to provide the remote UE with the first indication of the offset based on a first capability of the first relay UE for supporting to provide the first indication of the offset or based on a second capability of the second relay UE for supporting to provide the first indication of the offset; and determining whether the first relay UE supports to provide the remote UE with the first indication of the offset based on the fifth indication.

20. A remote user equipment (UE), comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

receive a second indication via the transceiver from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between a system frame number (SFN) timeline and a direct frame number (DFN) timeline, and the remote UE is to be connected to or is connected to a network entity via the first relay UE and a second relay UE.

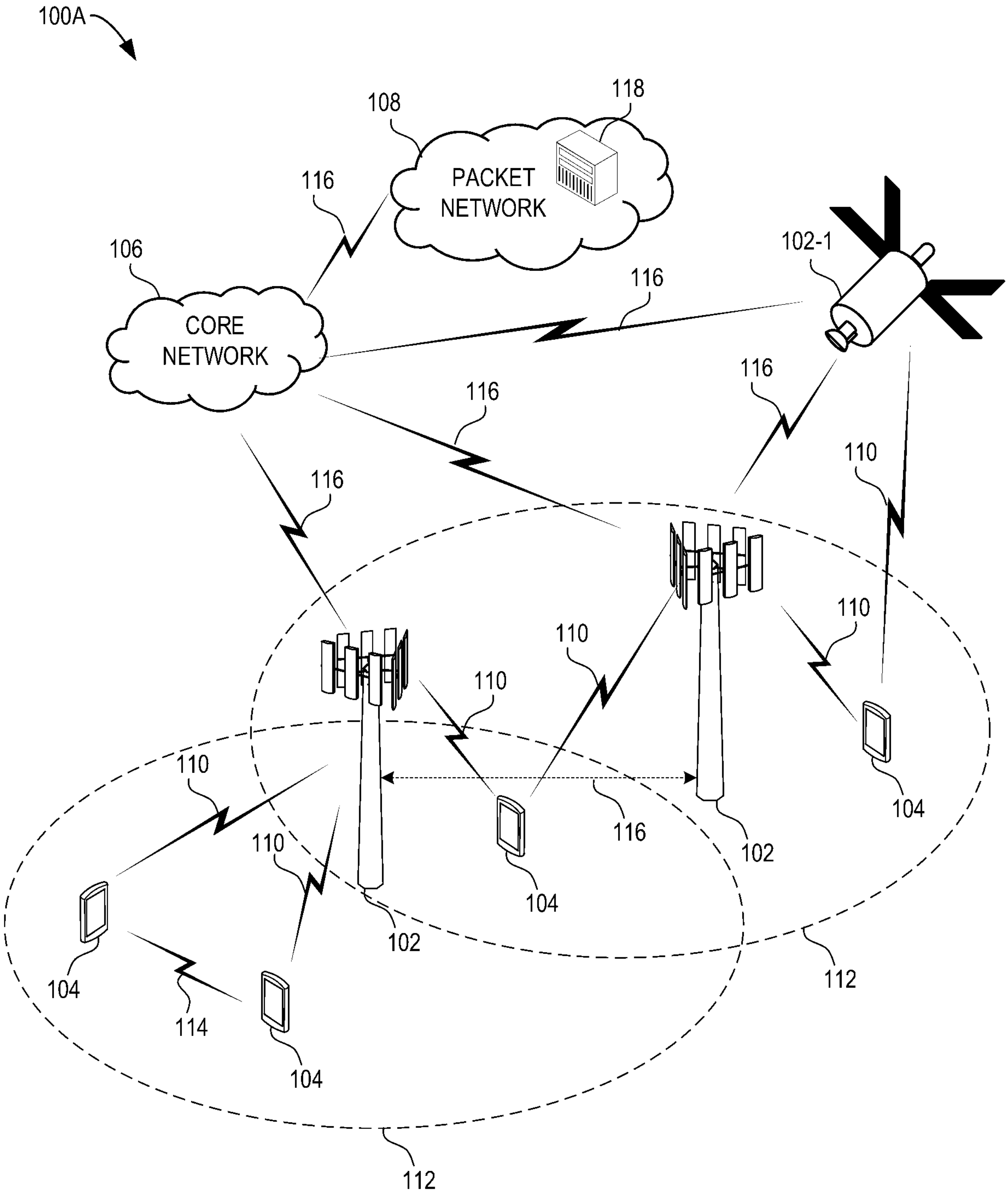
100A
108
118
PACKET
NETWORK
116
106
CORE
NETWORK
116
102-1
116
116
116
110
116
110
110
110
110
104
116
102
110
110
104
102
104
114
112
104
112

Fig. 1A

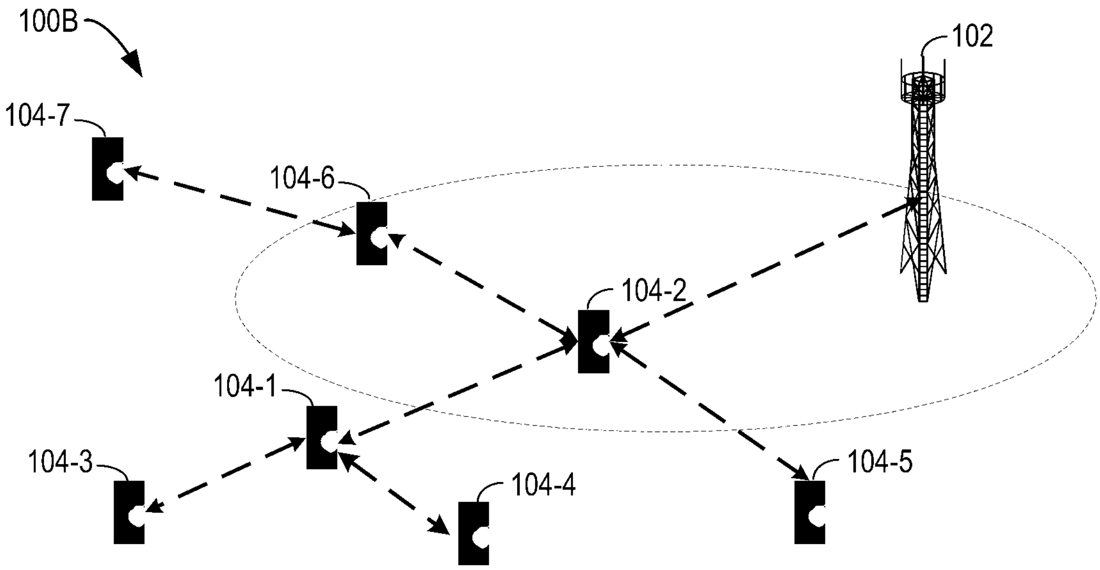
100B
102
104-7
104-6
104-2
104-1
104-3
104-4
104-5

Fig. 1B

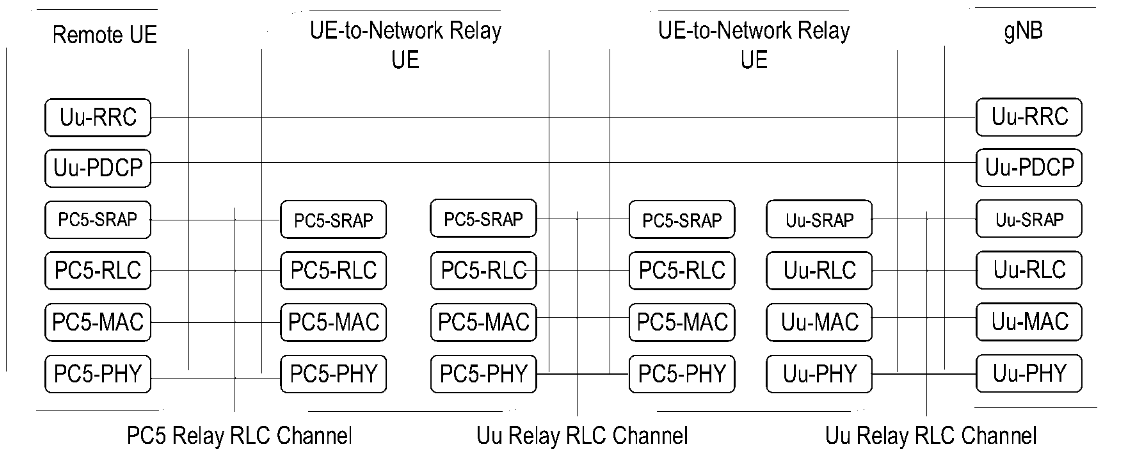
Remote UE
UE-to-Network Relay UE
UE-to-Network Relay UE
gNB
Uu-RRC
Uu-PDCP
PC5-SRAP
PC5-RLC
PC5-MAC
PC5-PHY
PC5-SRAP
PC5-RLC
PC5-MAC
PC5-PHY
PC5-SRAP
PC5-RLC
PC5-MAC
PC5-PHY
PC5-SRAP
PC5-RLC
PC5-MAC
PC5-PHY
Uu-SRAP
Uu-RLC
Uu-MAC
Uu-PHY
Uu-RRC
Uu-PDCP
Uu-SRAP
Uu-RLC
Uu-MAC
Uu-PHY
PC5 Relay RLC Channel
Uu Relay RLC Channel
Uu Relay RLC Channel

Fig. 2

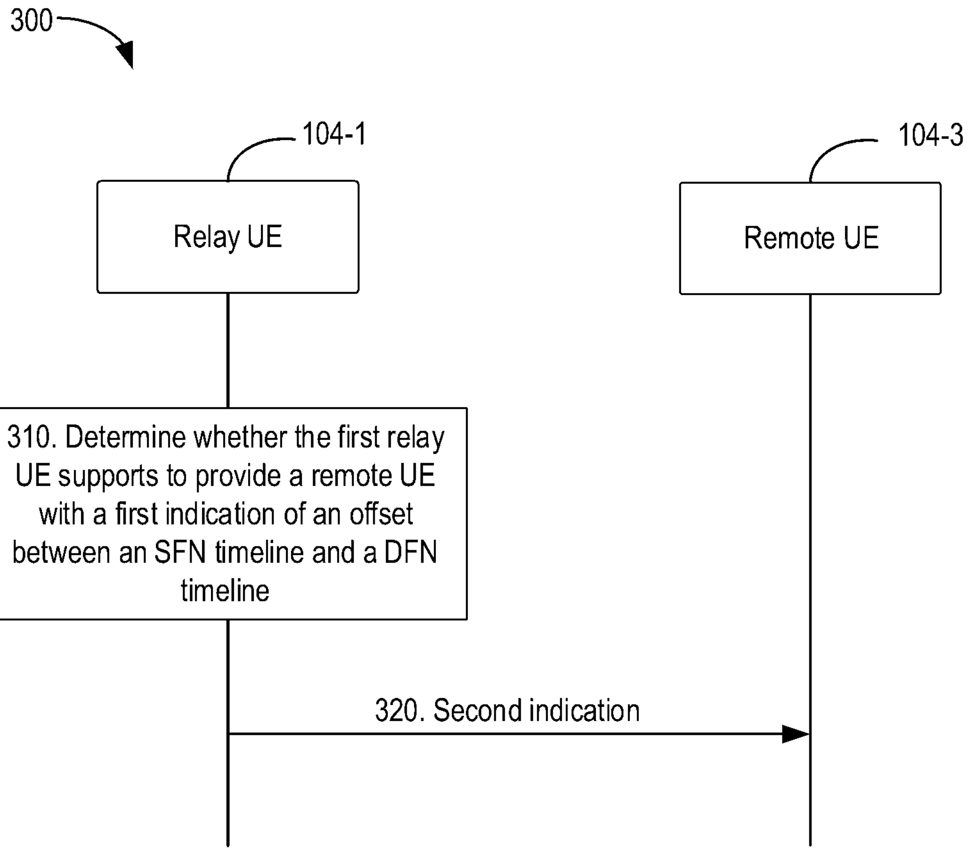
300
104-1
104-3
Relay UE
Remote UE
310. Determine whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline
320. Second indication

Fig. 3

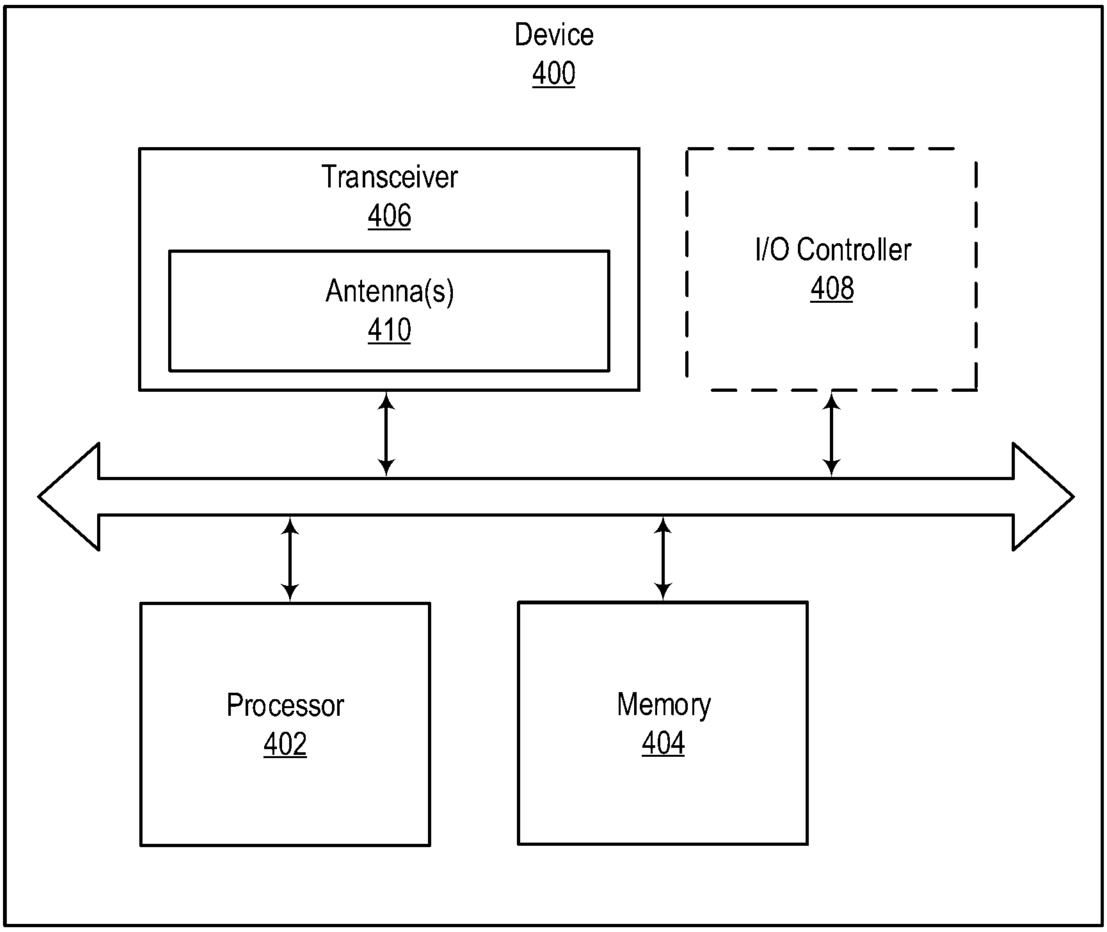
Device
400
Transceiver
406
Antenna(s)
410
I/O Controller
408
Processor
402
Memory
404

Fig. 4

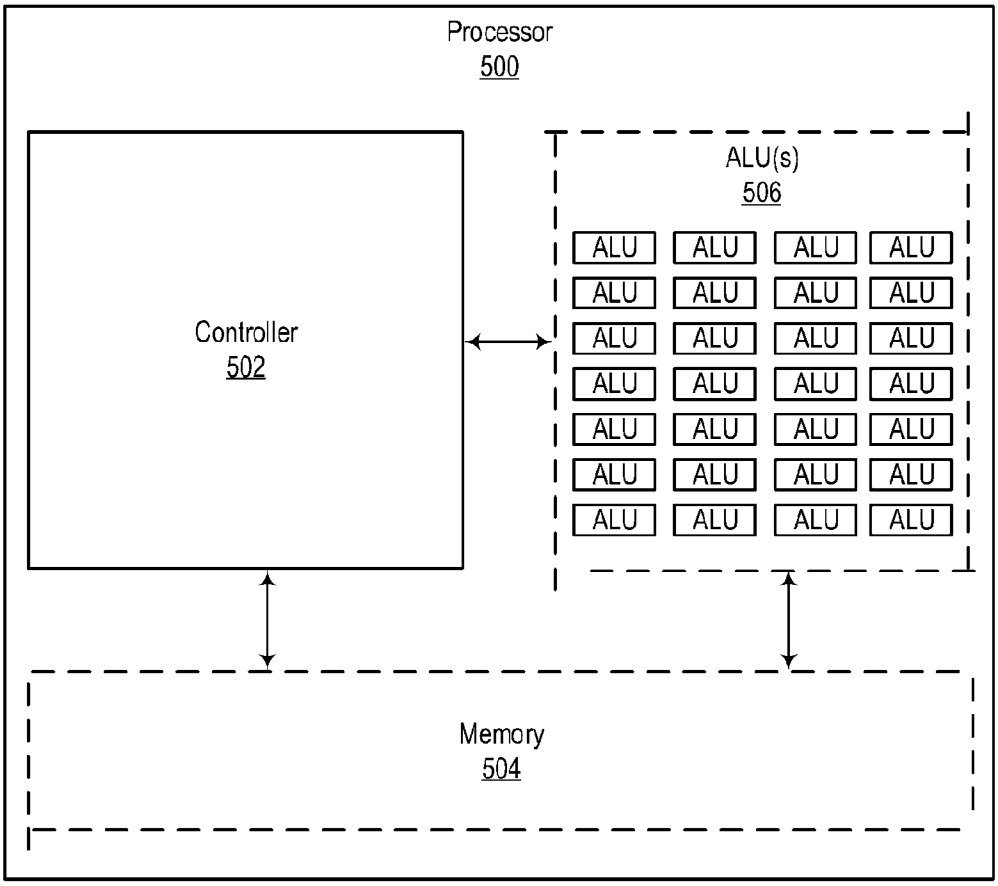

Fig. 5

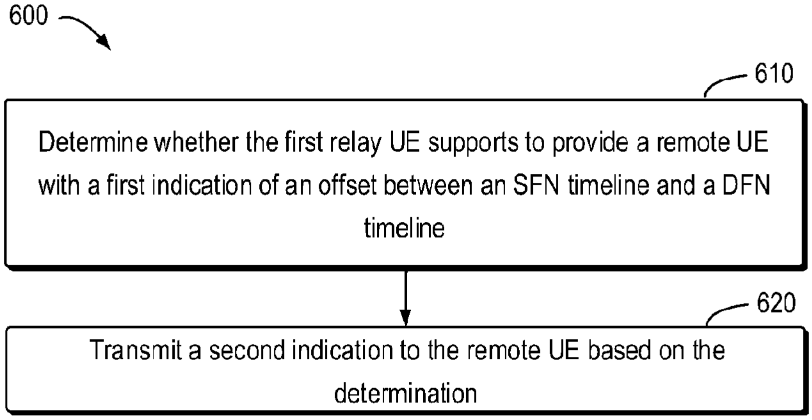
600
610
Determine whether the first relay UE supports to provide a remote UE with a first indication of an offset between an SFN timeline and a DFN timeline
620
Transmit a second indication to the remote UE based on the determination

Fig. 6

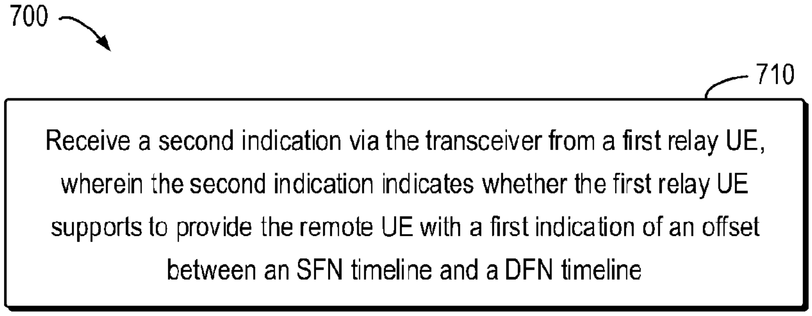
700
710
Receive a second indication via the transceiver from a first relay UE, wherein the second indication indicates whether the first relay UE supports to provide the remote UE with a first indication of an offset between an SFN timeline and a DFN timeline

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/085267

A. CLASSIFICATION OF SUBJECT MATTER

H04W 40/22(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,DWPI,EPODOC,3GPP,ENTXTC,CNABS:relay,UE,remote,offset,timeline,DFN,SFN,indication,connect,system frame number,direct frame number

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2023236706 A1 (MEDIATEK INC.) 14 December 2023 (2023-12-14) description, paragraphs 0006-0008,0027-0045	1-20
A	CN 111886908 A (QUALCOMM INCORPORATED) 03 November 2020 (2020-11-03) the whole document	1-20
A	CN 114930975 A (QUALCOMM INCORPORATED) 19 August 2022 (2022-08-19) the whole document	1-20

☐ 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	Date of mailing of the international search report
06 December 2024	**23 December 2024**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/085267

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2023236706	A1	14 December 2023	TW	202349979	A	16 December 2023
				CN	118679716	A	20 September 2024
				WO	2023236141	A1	14 December 2023
CN	111886908	A	03 November 2020	EP	3747221	A1	09 December 2020
				US	2019289561	A1	19 September 2019
				WO	2019177848	A1	19 September 2019
				CN	111886908	A	03 November 2020
				IN	202027043097	A	25 December 2020
CN	114930975	A	19 August 2022	EP	4091397	A1	23 November 2022
				US	2021219385	A1	15 July 2021
				WO	2021146206	A1	22 July 2021
				CN	114930975	A	19 August 2022
				IN	202227033680	A	16 September 2022