

METHODS AND APPARATUSES FOR A DISCOVERY MECHANISM IN A RELAY CASE WITH MULTIPLE HOPS

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to methods and apparatuses for a discovery mechanism in a relay case with multiple hops, e.g. in a Layer-2 (L2) UE-to-network (U2N) relay case with multiple hops.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (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-domain resources (e.g. symbols, slots, subframes, frames, or the like) or frequency-domain resources (e.g. subcarriers, carriers, or the like). 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] Sidelink relay is introduced to support 5G ProSe UE-to-Network Relay (U2N) function to provide connectivity to the network for U2N Remote UE. A U2N Relay UE shall be in RRC_CONNECTED to perform relaying of unicast data. In path switching case, a U2N Relay UE in RRC_IDLE, RRC_INACTIVE or RRC_CONNECTED state can be selected as a target relay UE.

SUMMARY

[0004] 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.

[0005] Some implementations of the present disclosure provide a first user equipment (UE). The first UE includes at least one memory; and at least one processor coupled to the at least one memory and configured to cause the first UE to: transmit a discovery message; and establish a first PC5 connection between the first UE and a first relay UE and establish a second PC5 connection between the first UE and a remote UE, wherein a connection between the first relay UE and a network node is established, and wherein the remote UE is expected to establish an end-to-end connection towards the network node via both the first UE and the first relay UE.

[0006] In some implementations of the first UE described herein, the processor of the first UE is configured to receive, from the network node, first information indicating whether the network node supports a multiple-hop sidelink layer 2 (L2) relay UE.

[0007] In some implementations of the first UE described herein, the processor of the first UE is configured to: determine whether a channel quality of a PC5 link between the first UE and the first relay UE is greater than or equal to a first threshold; and in response to that the channel quality of the PC5 link between the first UE and the first relay UE is greater than or equal to the first threshold, determine that the first UE can act as a multiple-hop relay UE.

[0008] In some implementations of the first UE described herein, in response to that the first UE can act as the multiple-hop relay UE, the first UE is allowed to transmit the discovery message or monitor another discovery message before establishing the first PC5 connection.

[0009] In some implementations of the first UE described herein, the processor of the first UE is configured to: in response to that a PC5 link between the remote UE and the first

UE is established after the first UE transmitting the discovery message, trigger to establish an end-to-end connection between the first UE and the network node.

[0010] In some implementations of the first UE described herein, the first threshold is a pre-configured threshold.

[0011] In some implementations of the first UE described herein, in response to that the first PC5 connection is established, the first UE is allowed to transmit the discovery message.

[0012] In some implementations of the first UE described herein, in response to that the first PC5 connection is established and an end-to-end connection between the first UE and the network node is established, the first UE is allowed to transmit the discovery message.

[0013] In some implementations of the first UE described herein, the processor of the first UE is configured to: determine whether a channel quality of a Uu link between the first UE and the network node is less than or equal to a second threshold; and in response to that the channel quality of the Uu link between the first UE and the network node is less than or equal to the second threshold, determine that the first UE can act as a multiple-hop relay UE.

[0014] In some implementations of the first UE described herein, in response to that the first UE can act as the multiple-hop relay UE, the processor of the first UE is configured to: determine whether a channel quality of a PC5 link between the first UE and the first relay UE is greater than or equal to a third threshold; and in response to that the channel quality of the PC5 link between the first UE and the first relay UE is greater than or equal to the third threshold, the first UE is allowed to transmit the discovery message before establishing the first PC5 connection.

[0015] In some implementations of the first UE described herein, the processor of the first UE is configured to receive, from the network node, first configuration information including the second threshold, the third threshold, or a combination thereof.

[0016] In some implementations of the first UE described herein, the first information, the first configuration information, or a combination thereof is received by the first UE from the network node via system information or dedicated signaling.

[0017] In some implementations of the first UE described herein, in response to that the first UE can act as the multiple-hop relay UE, the first UE is allowed to transmit the discovery

message in response to meeting one of the following conditions: the first PC5 connection is established and before establishing an end-to-end connection between the first UE and the network node; the end-to-end connection between the first UE and the network node is established; or the first UE is configured to transit to an RRC connected state, an RRC idle state or an RRC inactive state.

[0018] In some implementations of the first UE described herein, the processor of the first UE is configured to: receive an RRC setup request message from the remote UE; and transmit, to the first relay UE, the RRC setup request message on a signaling radio bearer (SRB) 0 using one of the following: a first PC5 relay radio link control (RLC) channel for the PC5 link between the first UE and the first relay UE configured by the network; and a specified PC5 relay RLC channel.

[0019] In some implementations of the first UE described herein, the processor of the first UE is configured to: receive, from the first relay UE, an RRC setup message on the SRB0 using one of the following: the first PC5 relay RLC channel; and the specified PC5 relay RLC channel.

[0020] In some implementations of the first UE described herein, the discovery message includes: information indicating whether to allow a relay UE to access the first UE such that the first UE can act as a parent relay UE of the relay UE; information indicating whether the first UE is an out of coverage (OOC) UE or an in-coverage (IC) UE with reference to the network node; information indicating whether the first UE is a single-hop relay UE or a multiple-hop relay UE towards the network node; information indicating whether a backhaul (BH) between the first UE and the network node is established, in response to that the first UE is the multiple-hop relay UE towards the network node; a total number of hops between the first UE and the network node; time duration in which the first UE can provide service if the first UE acts as the multiple-hop relay UE; information indicating whether there is one or more connected remote UEs a PC5 connection between which and the first UE is established; a total number of the one or more connected remote UEs; channel quality of a PC5 link between the first UE and the first relay UE; channel quality of a Uu link between the first UE and the network node, in response to that the first UE is in coverage of the network node; or a combination thereof.

[0021] Some implementations of the present disclosure provide a processor for wireless communication, comprising at least one controller coupled with at least one memory and configured to cause the processor to: transmit a discovery message; and establish a first PC5 connection between a first UE and a first relay UE and establish a second PC5 connection between the first UE and a remote UE, wherein a connection between the first relay UE and a network node is established, and wherein the remote UE is expected to establish an end-to-end connection towards the network node via both the first UE and the first relay UE.

[0022] Some implementations of the present disclosure provide a method performed by a first user equipment (UE). The method includes: transmitting a discovery message; and establishing a first PC5 connection between the first UE and a first relay UE and establishing a second PC5 connection between the first UE and a remote UE, wherein a connection between the first relay UE and a network node is established, and wherein the remote UE is expected to establish an end-to-end connection towards the network node via both the first UE and the first relay UE.

[0023] Some implementations of the present disclosure provide a first relay user equipment (UE). The first relay UE includes at least one memory; and at least one processor coupled to the at least one memory and configured to cause the first relay UE to: transmit a first discovery message; and establish a first PC5 connection between the first relay UE and a second relay UE, wherein a connection between the first relay UE and a network node is established, and wherein a remote UE is expected to establish an end-to-end connection towards the network node via both the second relay UE and the first relay UE.

[0024] In some implementations of the first relay UE described herein, the processor of the first relay UE is configured to receive, from the network node, first information indicating whether the network node supports a multiple-hop sidelink layer 2 (L2) relay UE.

[0025] In some implementations of the first relay UE described herein, the processor of the first relay UE is configured to receive a second discovery message from the second relay UE before or after establishing the first PC5 connection.

[0026] In some implementations of the first relay UE described herein, the second discovery message is received from the second relay UE in response to that: the first PC5 connection is established; an end-to-end connection between the second relay UE and the

network node is established; and the second relay UE transits to an RRC connected state, an RRC idle state or an RRC inactive state.

[0027] In some implementations of the first relay UE described herein, the second discovery message includes: information indicating whether to allow a relay UE to access the second relay UE such that the second relay UE can act as a parent relay UE of the relay UE; information indicating whether the second relay UE is an out of coverage (OOC) UE or an in-coverage (IC) UE with reference to the network node; information indicating whether the second relay UE is a single-hop relay UE or a multiple-hop relay UE towards the network node; information indicating whether a backhaul (BH) between the second relay UE and the network node is established, in response to that the second relay UE is the multiple-hop relay UE towards the network node; a total number of hops between the second relay UE and the network node; time duration in which the second relay UE can provide service if the second relay UE acts as the multiple-hop relay UE; information indicating whether there is one or more connected remote UEs a PC5 connection between which and the second relay UE is established; a total number of the one or more connected remote UEs; channel quality of a PC5 link between the second relay UE and the first relay UE; channel quality of a Uu link between the second relay UE and the network node, in response to that the second relay UE is in coverage of the network node; or a combination thereof.

[0028] In some implementations of the first relay UE described herein, the processor of the first relay UE is configured to: receive, from the second relay UE, an RRC setup request message on a signaling radio bearer (SRB) 0 using one of the following: a first PC5 relay radio link control (RLC) channel for a PC5 link between the second relay UE and the first relay UE configured by the network; and a specified PC5 relay RLC channel.

[0029] In some implementations of the first relay UE described herein, the processor of the first relay UE is configured to: transmit, to the second relay UE, an RRC setup message on the SRB0 using one of the following: the first PC5 relay RLC channel; and the specified PC5 relay RLC channel.

[0030] In some implementations of the first relay UE described herein, the first discovery message includes: information indicating whether to allow a relay UE to access the first relay UE such that the first relay UE can act as a parent relay UE of the relay UE; information indicating whether the first relay UE is an out of coverage (OOC) UE or an in-coverage (IC)

UE with reference to the network node; information indicating whether the first relay UE is a single-hop relay UE or a multiple-hop relay UE towards the network node; information indicating whether a backhaul (BH) between the first relay UE and the network node is established, in response to that the first relay UE is the multiple-hop relay UE towards the network node; a total number of hops between the first relay UE and the network node; time duration in which the first relay UE can provide service if the first relay UE acts as the multiple-hop relay UE; information indicating whether there is one or more connected remote UEs a PC5 connection between which and the first relay UE is established; a total number of the one or more connected remote UEs; channel quality of a Uu link between the first relay UE and the network node, in response to that the first relay UE is in coverage of the network node; or a combination thereof.

[0031] Some implementations of the present disclosure provide a processor for wireless communication, comprising at least one controller coupled with at least one memory and configured to cause the processor to: transmit a first discovery message; and establish a first PC5 connection between a first relay UE and a second relay UE, wherein a connection between the first relay UE and a network node is established, and wherein a remote UE is expected to establish an end-to-end connection towards the network node via both the second relay UE and the first relay UE.

[0032] Some implementations of the present disclosure provide a method performed by a first relay user equipment (UE). The method includes: transmitting a first discovery message; and establishing a first PC5 connection between the first relay UE and a second relay UE, wherein a connection between the first relay UE and a network node is established, and wherein a remote UE is expected to establish an end-to-end connection towards the network node via both the second relay UE and the first relay UE.

[0033] Some implementations of the present disclosure provide a network node. The network node includes at least one memory; and at least one processor coupled to the at least one memory and configured to cause the network node to: receive, from a user equipment (UE), capability of the UE for supporting a multiple-hop sidelink layer 2 (L2) relay UE; and transmit information indicating whether the network node supports the multiple-hop sidelink L2 relay UE.

[0034] In some implementations of the network node described herein, the UE includes at least one of: a remote UE, a single-hop relay UE, or a multiple-hop relay UE.

[0035] In some implementations of the network node described herein, the processor of the network node is configured to transmit at least one of the following to the UE: first configuration information regarding a first threshold associated with a channel quality of a PC5 link between the UE and a first relay UE; second configuration information regarding a second threshold associated with a channel quality of a Uu link between the UE and the network node; or third configuration information regarding a PC5 relay radio link control (RLC) channel configured for the PC5 link between the UE and the first relay UE.

[0036] In some implementations of the network node described herein, the first configuration information, the second configuration information, the third configuration information, or a combination thereof is transmitted via system information or dedicated signaling.

[0037] Some implementations of the present disclosure provide a processor for wireless communication, comprising at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a user equipment (UE), capability of the UE for supporting a multiple-hop sidelink layer 2 (L2) relay UE; and transmit information indicating whether a network node supports the multiple-hop sidelink L2 relay UE.

[0038] Some implementations of the present disclosure provide a method performed by a network node. The method includes: receiving, from a user equipment (UE), capability of the UE for supporting a multiple-hop sidelink layer 2 (L2) relay UE; and transmitting information indicating whether the network node supports the multiple-hop sidelink L2 relay UE. In the embodiments of the present disclosure, the relay UE could be a UE-to-network relay UE which is a UE that provides functionality to support connectivity to the network for U2N Remote UE(s).

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0040] Figure 2 illustrates an example of a user equipment (UE) 200 in accordance with aspects of the present disclosure.

[0041] Figure 3 illustrates an example of a processor 300 in accordance with aspects of the present disclosure.

[0042] Figure 4 illustrates an example of a network equipment (NE) 400 in accordance with aspects of the present disclosure.

[0043] Figure 5A illustrates a schematic diagram of a wireless communication system in accordance with aspects of the present disclosure.

[0044] Figure 5B illustrates a schematic diagram of a relay based wireless communication system in accordance with aspects of the present disclosure.

[0045] Figure 5C illustrates an exemplary procedure for a notification message in accordance with aspects of the present disclosure.

[0046] Figure 6 illustrates a schematic diagram of a relay based wireless communication system in accordance with aspects of the present disclosure.

[0047] Figures 7-9 illustrate flowcharts of methods related to an L2 U2N relay case in accordance with aspects of the present disclosure.

[0048] Figures 10-12 illustrate schematic diagrams of an L2 U2N relay case in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0049] The detailed description of the appended drawings is intended as a description of the preferred embodiments of the present disclosure and is not intended to represent the only form in which the present disclosure may be practiced. It should be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the present disclosure.

[0050] Reference will now be made in detail to some embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. To facilitate understanding, embodiments are provided under specific network architectures and new service scenarios, such as the 3rd generation partnership project (3GPP) 5G (NR), 3GPP

long-term evolution (LTE) Release 8, and so on. It is contemplated that along with the developments of network architectures and new service scenarios, all embodiments in the present disclosure are also applicable to similar technical problems; and moreover, the terminologies recited in the present disclosure may change, which should not affect the principles of the present disclosure.

[0051] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. 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 NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) 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, for example, 6G. 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.

[0052] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g. receive signaling, transmit signaling) over a Uu interface.

[0053] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 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, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0054] The one or more UE 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 remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver 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.

[0055] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. 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 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.

[0056] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g. S1, N2, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g. via the CN 106). In some implementations, one or more NE 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).

[0057] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 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 NE 102 associated with the CN 106.

[0058] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g. via an S1, N2, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g. a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g. control information, data, and the like) between the UE 104 and the application server 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 CN 106 (e.g. one or more network functions of the CN 106).

[0059] In the wireless communications system 100, the NEs 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 NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 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 NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0060] 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. $\mu=0$) 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. $\mu=0$) associated with the first subcarrier spacing (e.g. 15 kHz) may utilize one slot per subframe. A second numerology (e.g. $\mu=1$) may be associated with a second subcarrier spacing (e.g. 30 kHz) and a normal cyclic prefix. A third numerology (e.g. $\mu=2$) 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. $\mu=3$) may be associated with a fourth subcarrier spacing (e.g. 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g. $\mu=4$) may be associated with a fifth subcarrier spacing (e.g. 240 kHz) and a normal cyclic prefix.

[0061] 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.

[0062] 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., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) 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. $\mu=0$) associated with a first subcarrier spacing (e.g. 15 kHz) may be used interchangeably between subframes and slots.

[0063] 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 (410 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 NEs 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 NEs 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 NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0064] 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. $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g. $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g. $\mu=2$), 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. $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g. $\mu=3$), which includes 120 kHz subcarrier spacing.

[0065] Figure 2 illustrates an example of a UE 200 in accordance with aspects of the present disclosure. The UE 200 may include a processor 202, a memory 204, a controller 206, and a transceiver 208. The processor 202, the memory 204, the controller 206, or the transceiver 208, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g. operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0066] The processor 202, the memory 204, the controller 206, or the transceiver 208, or various combinations or components thereof may be implemented in hardware (e.g. circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0067] The processor 202 may include an intelligent hardware device (e.g. a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 202 may be configured to operate the memory 204. In some other implementations, the memory 204 may be integrated into the processor 202. The processor 202 may be configured to execute computer-readable instructions stored in the memory 204 to cause the UE 200 to perform various functions of the present disclosure.

[0068] The memory 204 may include volatile or non-volatile memory. The memory 204 may store computer-readable, computer-executable code including instructions when executed by the processor 202 cause the UE 200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 204 or another type of memory. 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.

[0069] In some implementations, the processor 202 and the memory 204 coupled with the processor 202 may be configured to cause the UE 200 to perform one or more of the functions described herein (e.g. executing, by the processor 202, instructions stored in the memory 204).

[0070] For example, the processor 202 may support wireless communication at the UE 200 in accordance with examples as disclosed with respect to Figure 7. The UE 200 may be configured to support: a means for transmitting a discovery message; and a means for establishing a first PC5 connection between the first UE and a first relay UE and establishing a second PC5 connection between the first UE and a remote UE, wherein a connection between the first relay UE and a network node is established, and wherein the remote UE is

expected to establish an end-to-end connection towards the network node via both the first UE and the first relay UE.

[0071] For example, the processor 202 may support wireless communication at the UE 200 in accordance with examples as disclosed with respect to Figure 8. The UE 200 may be configured to support: a means for transmitting a first discovery message; and a means for establishing a first PC5 connection between the first relay UE and a second relay UE, wherein a connection between the first relay UE and a network node is established, and wherein a remote UE is expected to establish an end-to-end connection towards the network node via both the second relay UE and the first relay UE.

[0072] The controller 206 may manage input and output signals for the UE 200. The controller 206 may also manage peripherals not integrated into the UE 200. In some implementations, the controller 206 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 206 may be implemented as part of the processor 202.

[0073] In some implementations, the UE 200 may include at least one transceiver 208. In some other implementations, the UE 200 may have more than one transceiver 208. The transceiver 208 may represent a wireless transceiver. The transceiver 208 may include one or more receiver chains 210, one or more transmitter chains 212, or a combination thereof. The means for receiving abovementioned in the processor 202 or the means for transmitting in the processor 202 may be implemented via at least one transceiver 208.

[0074] A receiver chain 210 may be configured to receive signals (e.g. control information, data, packets) over a wireless medium. For example, the receiver chain 210 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 210 may include at least one amplifier (e.g. a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 210 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 receiver chain 210 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0075] A transmitter chain 212 may be configured to generate and transmit signals (e.g. control information, data, packets). The transmitter chain 212 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 transmitter chain 212 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 transmitter chain 212 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0076] Figure 3 illustrates an example of a processor 300 in accordance with aspects of the present disclosure. The processor 300 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 300 may include a controller 302 configured to perform various operations in accordance with examples as described herein. The processor 300 may optionally include at least one memory 304, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 300 may optionally include one or more arithmetic-logic units (ALUs) 306. 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).

[0077] The processor 300 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 300) 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).

[0078] The controller 302 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 300 to cause the processor 300 to support various operations in accordance with examples as described herein. For example, the controller 302 may operate as a control unit of the processor 300, generating control signals that manage the operation of various components of the processor 300. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0079] The controller 302 may be configured to fetch (e.g. obtain, retrieve, receive) instructions from the memory 304 and determine subsequent instruction(s) to be executed to cause the processor 300 to support various operations in accordance with examples as described herein. The controller 302 may be configured to track memory address of instructions associated with the memory 304. The controller 302 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 302 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 300 to cause the processor 300 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 302 may be configured to manage flow of data within the processor 300. The controller 302 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 300.

[0080] The memory 304 may include one or more caches (e.g. memory local to or included in the processor 300 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 304 may reside within or on a processor chipset (e.g. local to the processor 300). In some other implementations, the memory 304 may reside external to the processor chipset (e.g. remote to the processor 300).

[0081] The memory 304 may store computer-readable, computer-executable code including instructions that, when executed by the processor 300, cause the processor 300 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 302 and/or the processor 300 may be configured to execute computer-readable

instructions stored in the memory 304 to cause the processor 300 to perform various functions. For example, the processor 300 and/or the controller 302 may be coupled with or to the memory 304, the processor 300, the controller 302, and the memory 304 may be configured to perform various functions described herein. In some examples, the processor 300 may include multiple processors and the memory 304 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.

[0082] The one or more ALUs 306 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 306 may reside within or on a processor chipset (e.g. the processor 300). In some other implementations, the one or more ALUs 306 may reside external to the processor chipset (e.g. the processor 300). One or more ALUs 306 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 306 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 306 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 306 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 306 to handle conditional operations, comparisons, and bitwise operations.

[0083] The processor 300 may support wireless communication in accordance with examples as disclosed herein.

[0084] In some implementations, the processor 300 may be configured to support a means for performing operations of a UE as described with respect to Figure 7. The processor 300 may be configured to or operable to support: a means for transmitting a discovery message; and a means for establishing a first PC5 connection between the first UE and a first relay UE and establishing a second PC5 connection between the first UE and a remote UE, wherein a connection between the first relay UE and a network node is established, and wherein the remote UE is expected to establish an end-to-end connection towards the network node via both the first UE and the first relay UE.

[0085] In some implementations, the processor 300 may be configured to support a means for performing operations of a UE as described with respect to Figure 8. The processor 300 may be configured to or operable to support: a means for transmitting a first discovery message; and a means for establishing a first PC5 connection between the first relay UE and a second relay UE, wherein a connection between the first relay UE and a network node is established, and wherein a remote UE is expected to establish an end-to-end connection towards the network node via both the second relay UE and the first relay UE.

[0086] In some implementations, the processor 300 may be configured to support a means for performing operations of a serving BS as described with respect to Figure 9. The processor 300 may be configured to or operable to support: a means for receiving, from a user equipment (UE), capability of the UE for supporting a multiple-hop sidelink layer 2 (L2) relay UE; and a means for transmitting information indicating whether the network node supports the multiple-hop sidelink L2 relay UE.

[0087] It should be appreciated by persons skilled in the art that the components in exemplary processor 300 may be changed, for example, some of the components in exemplary processor 300 may be omitted or modified or new component(s) may be added to exemplary processor 300, without departing from the spirit and scope of the disclosure. For example, in some embodiments, the processor 300 may not include the ALUs 306.

[0088] Figure 4 illustrates an example of a NE 400 in accordance with aspects of the present disclosure. The NE 400 may include a processor 402, a memory 404, a controller 406, and a transceiver 408. The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g. operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0089] The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations or components thereof may be implemented in hardware (e.g. circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0090] The processor 402 may include an intelligent hardware device (e.g. a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 402 may be configured to operate the memory 404. In some other implementations, the memory 404 may be integrated into the processor 402. The processor 402 may be configured to execute computer-readable instructions stored in the memory 404 to cause the NE 400 to perform various functions of the present disclosure.

[0091] The memory 404 may include volatile or non-volatile memory. The memory 404 may store computer-readable, computer-executable code including instructions when executed by the processor 402 cause the NE 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 404 or another type of memory. 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.

[0092] In some implementations, the processor 402 and the memory 404 coupled with the processor 402 may be configured to cause the NE 400 to perform one or more of the functions described herein (e.g. executing, by the processor 402, instructions stored in the memory 404). For example, the processor 402 may support wireless communication at the NE 400 in accordance with examples as disclosed herein. For example, the NE 400 may be configured to support a means for performing the operations as described with respect to Figures 7 and 8 as described below.

[0093] In some implementations, the NE 400 may be a network node as described with respect to Figure 9. The NE 400 may be configured to or operable to support: a means for receiving, from a user equipment (UE), capability of the UE for supporting a multiple-hop sidelink layer 2 (L2) relay UE; and a means for transmitting information indicating whether the network node supports the multiple-hop sidelink L2 relay UE.

[0094] The controller 406 may manage input and output signals for the NE 400. The controller 406 may also manage peripherals not integrated into the NE 400. In some implementations, the controller 406 may utilize an operating system such as iOS®,

ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 406 may be implemented as part of the processor 402.

[0095] In some implementations, the NE 400 may include at least one transceiver 408. In some other implementations, the NE 400 may have more than one transceiver 408. The transceiver 408 may represent a wireless transceiver. The transceiver 408 may include one or more receiver chains 410, one or more transmitter chains 412, or a combination thereof. The means for receiving or the means for transmitting abovementioned in the processor 402 may be implemented via at least one transceiver 408.

[0096] A receiver chain 410 may be configured to receive signals (e.g. control information, data, packets) over a wireless medium. For example, the receiver chain 410 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 410 may include at least one amplifier (e.g. a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 410 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 receiver chain 410 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0097] A transmitter chain 412 may be configured to generate and transmit signals (e.g. control information, data, packets). The transmitter chain 412 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 transmitter chain 412 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 transmitter chain 412 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0098] It should be appreciated by persons skilled in the art that the components in exemplary NE 400 may be changed, for example, some of the components in exemplary NE 400 may be omitted or modified or new component(s) may be added to exemplary NE 400,

without departing from the spirit and scope of the disclosure. For example, in some embodiments, the NE 400 may not include the controller 406.

[0099] Figure 5A illustrates a schematic diagram of a wireless communication system in accordance with aspects of the present disclosure. As shown in Figure 5A, the wireless communication system 100 may support sidelink communications. Sidelink communication supports UE-to-UE direct communication. In the context of the present disclosure, sidelink communications may be categorized according to the wireless communication technologies adopted. For example, sidelink communication may include NR sidelink communication and V2X sidelink communication.

[0100] NR sidelink communications (e.g., specified in 3GPP TS 38 series specification) may refer to access stratum (AS) functionality enabling at least vehicle-to-everything (V2X) communications between neighboring UEs, using NR technology but not traversing any network node. V2X sidelink communications (e.g., specified in 3GPP TS 36 series specification) may refer to AS functionality enabling V2X communications between neighboring UEs, using evolved-universal mobile telecommunication system (UMTS) terrestrial radio access (UTRA) (E-UTRA) technology, but not traversing any network node. However, if not being specified, "sidelink communications" may refer to NR sidelink communications, V2X sidelink communications, or any sidelink communications adopting other wireless communication technologies.

[0101] Referring to Figure 5A, wireless communication system 100 may include some base stations (e.g., BS 105 and BS 103) and some UEs (e.g., UE 101A, UE 101B, and UE 101C). Although a specific number of UEs and BSs are depicted in Figure 5A, it is contemplated that any number of UEs and BSs may be included in the wireless communication system 100.

[0102] The UEs and the BSs may support communication based on, for example, 3G, long-term evolution (LTE), LTE-advanced (LTE-A), new radio (NR), or other suitable protocol(s). In some embodiments of the present disclosure, a BS (e.g., BS 105 or BS 103) may be referred to as an access point, an access terminal, a base, a base unit, a macro cell, a Node-B, an evolved Node B (eNB), a gNB, an ng-eNB, a Home Node-B, a relay node, or a device, or described using other terminology used in the art. A UE (e.g., UE 101A, UE 101B,

or UE 101C) may include, for example, but is not limited to, a computing device, a wearable device, a mobile device, an IoT device, a vehicle, etc.

[0103] In the example of Figure 5A, BS 105 and BS 103 may be included in a next generation radio access network (NG-RAN). In some embodiments of the present disclosure, BS 105 may be a gNB and BS 103 may be an ng-eNB.

[0104] UE 101A and UE 101B may be in-coverage (e.g., inside the NG-RAN). For example, as shown in Figure 5A, UE 101A may be within the coverage of BS 105, and UE 101B may be within the coverage of BS 103. UE 101C may be out-of-coverage (e.g., outside the coverage of the NG-RAN). For example, as shown in Figure 5A, UE 101C may be outside the coverage of any BS, for example, both BS 105 and BS 103. UE 101A and UE 101B may respectively connect to BS 105 and BS 103 via a network interface, for example, the Uu interface as specified in 3GPP specification. The control plane protocol stack in the Uu interface may include an RRC layer, which may be referred to as a Uu RRC. The link established between a UE (e.g., UE 101A) and a BS (e.g., BS 105) may be referred to as a Uu link. BS 105 and BS 103 may be connected to each other via a network interface, for example, the Xn interface as specified in 3GPP standard documents. UE 101A, UE 101B, and UE 101C may be connected to each other respectively via, for example, a PC5 interface as specified in 3GPP standard documents. The control plane protocol stack in the PC5 interface may include an RRC layer, which may be referred to as a PC5 RRC. The link established between two UEs (e.g., UE 101A and UE 101B) may be referred to as a PC5 link.

[0105] Support for V2X services via the PC5 interface can be provided by, for example, NR sidelink communication and/or V2X sidelink communication. NR sidelink communication can support one of the following three types of transmission modes for a pair of a source Layer-2 identity and a destination Layer-2 identity: unicast transmission, groupcast transmission, and broadcast transmission. Sidelink communication transmission and reception over the PC5 interface are supported when the UE is either in-coverage or out-of-coverage. For example, UE 101A, which is within the coverage of BS 105, can perform sidelink transmission and reception (e.g., sidelink unicast transmission, sidelink groupcast transmission, or sidelink broadcast transmission) over a PC5 interface. UE 101C, which is outside the coverage of both BS 105 and BS 103, can also perform sidelink transmission(s) and reception(s) over a PC5 interface.

[0106] A UE which supports sidelink communication and/or V2X communication may be referred to as a V2X UE. A V2X UE may be a cell phone, a vehicle, a roadmap device, a computer, a laptop, an IoT (internet of things) device or other type of device in accordance with some other embodiments of the present disclosure.

[0107] As mentioned above, the relaying function based on a sidelink may be supported in a communication network. A Sidelink relay can provide connectivity to the network for another UE (remote UE). In some embodiments of the present disclosure, a UE-to-network (U2N) relay is supported. For example, an in-coverage (IC) UE in communication with a remote UE (e.g., an out-of-coverage (OOC) UE or an IC UE) may function as a relay UE between the serving BS of the IC UE and the remote UE. The remote UE may thus communicate with the BS via this relay UE. The data between the remote UE and the BS may be transferred by the relay UE. In this scenario, the relay UE may be referred to as a serving relay of the remote UE, and the serving BS or serving cell of the relay UE may be respectively referred to as the serving BS or serving cell of the remote UE.

[0108] In the present disclosure, a remote UE may have RRC states, such as an RRC_IDLE state, an RRC_INACTIVE state, and an RRC_CONNECTED state as defined in 3GPP specifications. An RRC_IDLE state may also be named as an RRC idle state or the like. An RRC_INACTIVE state may also be named as an RRC inactive state or the like. An RRC_CONNECTED state may also be named as an RRC connected state or the like. A relay UE may be in an RRC_CONNECTED state to perform relaying of unicast data.

[0109] In some embodiments, the following RRC state combinations may be supported for a L2 U2N Relay operation:

- Both the relay UE and the remote UE may be in an RRC_CONNECTED state to perform transmission or reception of relayed unicast data; and
- The relay UE can be in an RRC_IDLE, RRC_INACTIVE or RRC_CONNECTED state as long as every remote UE that is connected to the relay UE is either in an RRC_INACTIVE state or in an RRC_IDLE state.

[0110] A single unicast link may be established between one relay UE and one remote UE. The traffic of the remote UE via a given relay UE and the traffic of the relay UE may be separated in different Uu relay radio link control (RLC) channels. In some embodiments,

for the L2 U2N relay, the remote UE may only be configured to use resource allocation mode 2 for data to be relayed.

[0111] Figure 5B illustrates a schematic diagram of a relay based wireless communication system in accordance with aspects of the present disclosure. Details described in all of the foregoing embodiments of the present disclosure are applicable for the embodiments shown in Figure 5B.

[0112] As shown in Figure 5B, a wireless communication system may include a BS (e.g., BS #1) and some UEs (e.g., relay UE #1 and remote UE #1). Although a specific number of UEs and BS is depicted in Figure 5B, it is contemplated that any number of UEs and BSs may be included in the wireless communication system. In some examples, relay UE #1 may function as UE 101A or UE 101B shown in Figure 5A, and remote UE #1 may function as UE 101C shown in Figure 5A.

[0113] As shown in Figure 5B, relay UE #1 is within the coverage of BS #1. For example, relay UE #1 and BS #1 may establish an RRC connection therebetween. Remote UE #1 is outside of the coverage of BS #1. The wireless communication system in Figure 5B may support sidelink communications. For example, relay UE #1 is in sidelink communication with remote UE #1. A PC5 RRC connection may be established between remote UE #1 and relay UE #1.

[0114] In some embodiments of the present disclosure, remote UE #1 may initiate a procedure for establishing a connection with BS #1 via relay UE #1 (i.e., U2N relay). After such procedure, remote UE #1 may access BS #1 (e.g., a cell of BS #1) via relay UE #1. This cell may be referred to as a serving cell of remote UE #1. Remote UE #1 and BS #1 may establish an RRC connection therebetween. Relay UE #1 may also be referred to as a relay UE, a sidelink relay, or a serving relay of remote UE #1.

[0115] It should be appreciated by persons skilled in the art that although a single relay node (e.g., relay UE #1) between remote UE #1 and BS #1 is depicted in Figure 5B, it is contemplated that any number of relay nodes may be included. Although it is shown in Figure 5B that remote UE #1 is outside of the coverage of BS #1, it is contemplated that remote UE #1 may be within the coverage of BS #1 in some other embodiments of the present

disclosure. In these embodiments, remote UE #1 may directly connect to BS #1 and/or connect to BS #1 via relay UE #1.

[0116] Figure 5C illustrates an exemplary procedure for a notification message in accordance with aspects of the present disclosure. Details described in all of the foregoing embodiments of the present disclosure are applicable for the embodiments shown in Figure 5C.

[0117] Referring to Figure 5C, in some embodiments, in operation 511, relay UE 503 may transmit a notification message to UE 501. In some examples, relay UE 503 may be a relay UE such as a U2N relay UE. In this scenario, the notification message may also be referred to as “a notification message for sidelink” or “notification message sidelink message” or the like.

[0118] In some embodiments of the present disclosure, relay UE 503 may initiate the exemplary procedure in Figure 5C when, for example, one of the following conditions is met:

- in response to a Uu RLF as will be described below; or
- in response to the reception of an RRC reconfiguration message including a reconfigurationWithSync information element (IE), such as a handover command; or
- in response to cell reselection at relay UE 503; or
- in response to an RRC connection failure at relay UE 503, which may include, for example, an RRC connection rejection, an expiry of a timer for RRC setup request (e.g., timer T300 as specified in 3GPP specifications), and an RRC resume failure.

[0119] The notification message may include a type indication (e.g., “indication type”), which may indicate that the notification message is due to one of a relay Uu RLF, relay handover, relay cell reselection, and/or relay connection failure.

[0120] Currently, details regarding a discovery mechanism in a Layer-2 (L2) UE-to-network (U2N) relay case (e.g. a multiple hop L2 U2N relay case) have not been specifically discussed yet in a wireless communication system or the like. For example, the following issues need to be solved: whether an out of coverage (OOC) UE can act as a child L2 relay UE; if yes, what criteria for "acting as a child L2 relay UE" may be configured to a UE; what is the condition for allowing an OOC child relay UE to perform a discovery mechanism;

whether an in-coverage (IC) UE can act as a child L2 relay UE; if yes, what criteria for "acting as a child L2 relay UE" may be configured to a UE; what is the condition for allowing an IC child relay UE to perform a discovery mechanism; and what information may be transmitted during the discovery mechanism by a parent relay UE and/or a child relay UE.

[0121] Embodiments of the present disclosure aim to resolve the abovementioned issues. In the embodiments of the present disclosure, a remote UE may access a serving BS (e.g. serving gNB) via two relay UEs, e.g. a first relay UE and a second relay UE. The first relay UE connects to the serving BS via Uu interface. The first relay UE can be called as a parent relay UE, a parent L2 relay UE, a parent L2 U2N relay UE, a parent sidelink relay, a first-hop relay UE, or a top relay UE or the like. The second relay UE connects to the serving BS via the first relay UE. The second relay UE can be called as a child relay UE, a child L2 relay UE, a child L2 U2N relay UE, a child sidelink relay, or a second-hop relay UE or the like. In the embodiments of the present disclosure, a discovery message may also be named as "a relay discovery message" or the like. A PC5 connection may also be named as "a PC5 RRC connection", "a PC5-S connection," or the like.

[0122] For example, some embodiments of the present disclosure provide the criteria for "acting as an L2 U2N relay UE" for an OOC UE. Some embodiments provide one or more conditions of allowing an OOC UE to transmit or monitor a discovery message. Some embodiments provide the criteria for "acting as L2 U2N relay UE" for an IC UE. Some embodiments of the present disclosure provide one or more conditions of allowing an IC UE to transmit or monitor a discovery message. Some embodiments of the present disclosure provide an enhanced discovery message, for example, additional information related to multiple hops is added in the discovery message. In some embodiments of the present disclosure, a network node (e.g. a BS) may broadcast whether to support a multi-hop sidelink (SL) L2 U2N relay.

[0123] In some embodiments of the present disclosure, the relay UE could be a UE-to-network relay UE which is a UE that provides functionality to support connectivity to the network for U2N Remote UE(s). More details of the embodiments of the present disclosure will be illustrated in the following text in combination with the appended drawings.

[0124] Figure 6 illustrates a schematic diagram of a relay based wireless communication system in accordance with aspects of the present disclosure. Details described in all of the

foregoing embodiments of the present disclosure are applicable for the embodiments shown in Figure 6. The embodiments of Figure 6 refer to a wireless communication system with architecture similar to that in Figure 5B. Some embodiments of the present disclosure aim to provide a discovery mechanism in the wireless communication system as shown in Figure 6. Specific examples are described in the embodiments of Figures 7-12 as follows.

[0125] The wireless communication system shown in Figure 6 includes BS #1 and some UEs (e.g., relay UE #1, relay UE #2, relay UE #3, remote UE #1 and remote UE #2). Although a specific number of UEs and BS is depicted in Figure 6, it is contemplated that any number of UEs and BSs may be included in the wireless communication system. In some examples, relay UE #1, relay UE #2, or relay UE #3 may function as UE 101A or UE 101B shown in Figure 5A, and remote UE #1 or remote UE #2 may function as UE 101C shown in Figure 5A.

[0126] As shown in Figure 6, relay UE #1 and relay UE #3 are within the coverage of BS #1, i.e. they are IC UEs. For example, relay UE #1 and BS #1 may establish an RRC connection therebetween. Relay UE #2, remote UE #1 and remote UE #2 are outside of the coverage of BS #1, i.e. they are OOC UEs. The wireless communication system in Figure 6 supports sidelink communications. For example, relay UE #2 is in sidelink communication with remote UE #1. A PC5 RRC connection may be established between remote UE #1 and relay UE #2. Relay UE #3 is in sidelink communication with remote UE #2. A PC5 RRC connection may be established between remote UE #2 and relay UE #3.

[0127] In some embodiments of the present disclosure, remote UE #1 may initiate a procedure for establishing a connection with BS #1 via both relay UE #1 and relay UE #2 (i.e., U2N relay). After such procedure, remote UE #1 may access BS #1 (e.g., a cell of BS #1) via relay UE #1 and relay UE #2. This cell may be referred to as a serving cell of remote UE #1. Remote UE #1 and BS #1 may establish an RRC connection therebetween. Relay UE #1 connects to serving BS #1 via Uu interface. Relay UE #1 may also be referred to as a first relay UE, first-hop relay UE, a top relay UE, a parent relay UE, a parent L2 relay UE, a parent L2 U2N relay UE, a parent sidelink relay, or a parent serving relay of remote UE #1, or the like. Relay UE #2 connects to the serving BS #1 via relay UE #1. Relay UE #2 may also be referred to as a second relay UE, a second-hop relay UE, a child relay UE, a child L2

relay UE, a child L2 U2N relay UE, a child sidelink relay, or a child serving relay of remote UE #1, or the like.

[0128] It should be appreciated by persons skilled in the art that although two relay nodes (e.g., relay UE #1 and relay UE #2) between remote UE #1 and BS #1 are depicted in Figure 6, it is contemplated that any number of relay nodes may be included.

[0129] In some embodiments of the present disclosure, remote UE #2 may initiate a procedure for establishing a connection with BS #1 via both relay UE #1 and relay UE #3 (i.e., U2N relay). After such procedure, remote UE #2 may access BS #1 (e.g., a cell of BS #1) via relay UE #1 and relay UE #3. This cell may be referred to as a serving cell of remote UE #2. Remote UE #1 and BS #1 may establish an RRC connection therebetween. Relay UE #1 connects to serving BS #1 via Uu interface. Relay UE #1 may also be referred to as a parent serving relay of remote UE #2 or the like. Relay UE #3 connects to the serving BS #1 via relay UE #1. Relay UE #3 may also be referred to as a second relay UE, a second-hop relay UE, a child relay UE, a child L2 relay UE, a child L2 U2N relay UE, a child sidelink relay, or a child serving relay of remote UE #1, or the like.

[0130] It should be appreciated by persons skilled in the art that although two relay nodes (e.g., relay UE #1 and relay UE #3) between remote UE #2 and BS #1 are depicted in Figure 6, it is contemplated that any number of relay nodes may be included.

[0131] Figure 7 illustrates a flowchart of a method related to an L2 U2N relay case in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE (which may act as a child relay UE) as described herein. The UE may be an OOC UE (e.g. relay UE #2 in Figure 6) or an IC UE (e.g. relay UE #3 in Figure 6). In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions. In some implementations, aspects of operations 702 and 704 may be performed by UE 200 as described with reference to Figure 2. Each of operations 702 and 704 may be performed in accordance with examples as described herein. Specific examples are described in the embodiments of Figures 10-12 as follows.

[0132] At operation 702, the method may include transmitting a discovery message (denoted as discovery message #1 for simplicity) by a UE (e.g. relay UE #2 or relay UE #3

in Figure 6). The discovery message may also be named as "a relay discovery message" or the like.

[0133] At operation 704, the method may include establishing a PC5 connection (denoted as PC5 connection #1) between the UE and a relay UE (e.g. relay UE #1 in Figure 6) and establishing a PC5 connection (denoted as PC5 connection #2) between the UE and a remote UE (e.g. remote UE #1 or remote UE #2 in Figure 6). In operation 704, a connection between the relay UE and a network node (e.g. BS #1 in Figure 6) has been established, e.g. via a Uu interface. The remote UE is expected to establish an end-to-end connection (e.g. an end-to-end RRC connection) towards the network node via both the UE (which act as a child relay UE) and the relay UE (which act as a parent relay UE). For example, as shown in Figure 6, remote UE #1 is expected to establish an end-to-end connection towards BS #1 via relay UE #2 and relay UE #1. Remote UE #2 is expected to establish an end-to-end connection towards BS #1 via relay UE #3 and relay UE #1.

[0134] The orders of performing operations 702 and 704 may be different in different embodiments. In some embodiments, discovery message #1 is transmitted by the UE before establishing PC5 connection #1 or PC5 connection #2. In some other embodiments, discovery message #1 is transmitted by the UE after establishing PC5 connection #1 or PC5 connection #2.

[0135] In some implementations, the UE may receive, from the network node, information indicating whether the network node supports a multiple-hop sidelink L2 relay UE. For example, the network node broadcasts the information via system information (e.g. a system information block (SIB)) or dedicated signaling. A specific example is described in the embodiments of Figure 12 as follows.

[0136] In some implementations, the UE may determine whether a channel quality of a PC5 link between the UE and the relay UE is greater than or equal to a threshold (denoted as threshold #1). If the channel quality of the PC5 link is greater than or equal to threshold #1, the UE may determine that the UE can act as a multiple-hop relay UE (e.g. a two or more hops relay UE), i.e., the UE is qualified to act a multiple-hop relay UE. For instance, the UE may be qualified to act a child relay UE, e.g. a second-hop relay UE or a third-hop relay UE with reference to a parent relay UE.

[0137] For instance, threshold #1 is a reference signal received power (RSRP) threshold. In an implementation, threshold #1 is a pre-configured threshold, e.g. if the UE is an OOC UE with reference to the network node. In another implementation, after the UE transits to an RRC connected state, an RRC idle state or an RRC inactive state, the UE may receive configuration information regarding threshold #1 from the network node, i.e. via broadcast signaling (e.g. SIB) or dedicated signaling.

[0138] In an implementation, if the UE determines that the UE can act as the multiple-hop relay UE, the UE is allowed to transmit discovery message #1 or monitor another discovery message before establishing PC5 connection #1. In some embodiments, if a PC5 link between the remote UE and the UE is established after the UE transmitting discovery message #1, the UE may trigger to establish an end-to-end connection (i.e. a control plane connection) between the UE (which acts as a child relay UE) and the network node.

[0139] For example, as shown in Figure 6, remote UE #1 may select relay UE #2 as a child relay UE after receiving discovery message #1 from relay UE #2 (e.g. if remote UE #1 receive one or more discovery messages from different candidate relay UEs), and a PC5 link between remote UE #1 and relay UE #2 may be established, e.g. based on a NR sidelink PC5 unicast link establishment procedure. Then, relay UE #2 may trigger to establish an end-to-end connection between relay UE #2 and BS #1.

[0140] In some implementations, if PC5 connection #1 is established, the UE is allowed to transmit discovery message #1. For example, after PC5 connection #1 is established, the UE is allowed to transmit discovery message #1 before establishing an end-to-end connection between the UE and BS #1. After transmitting discovery message #1, the UE may monitor a discovery message (denoted as discovery message #2) from the remote UE. Discovery message #2 may include similar information or elements to those of discovery message #1. A specific example is described in the embodiments of Figure 10 as follows.

[0141] In some implementations, if PC5 connection #1 is established and if an end-to-end connection between the UE and the network node is established, the UE is allowed to transmit discovery message #1. A specific example is described in the embodiments of Figure 11 as follows.

[0142] In some implementations, the UE may determine whether a channel quality of a Uu link between the UE and the network node is less than or equal to a threshold (denoted as threshold #2) (e.g. if the UE is an IC UE with reference to the network node). If the channel quality of the Uu link is less than or equal to threshold #2, the UE may determine that the UE can act as a multiple-hop relay UE. That is, the UE will connect to the network node via a parent child relay UE. Threshold #2 is Uu link threshold, e.g. a RSRP threshold. For example, threshold #2 may be a minimum Uu RSRP threshold configured by the network node.

[0143] In another implementation, if the UE determines that the UE can act as the multiple-hop relay UE, the UE may further determine whether a channel quality of a PC5 link between the UE and the relay UE is greater than or equal to a threshold (denoted as threshold #3). If the channel quality of the PC5 link is greater than or equal to threshold #3, the UE is allowed to transmit discovery message #1 before establishing PC5 connection #1. For example, the UE is allowed to transmit discovery message #1 in response to meeting one of the following conditions:

- (1) PC5 connection #1 is established, and before establishing an end-to-end connection between the UE and the network node;
- (2) the end-to-end connection between the UE and the network node is established;
- (3) the UE is configured to transit to an RRC connected state;
- (4) the UE is configured to transit to an RRC idle state; or
- (5) the UE is configured to transit to an RRC inactive state.

[0144] Threshold #3 is PC5 link threshold, e.g. a RSRP threshold. For example, the UE may receive configuration information including threshold #2 and/or threshold #3 from the network node, e.g. via system information (e.g. SIB) or dedicated signaling. A specific example is described in the embodiments of Figure 12 as follows.

[0145] In some implementations, the UE may receive an RRC setup request message from the remote UE, and transmit, to the relay UE, the RRC setup request message on SRB0 using:

- (1) a PC5 relay RLC channel for the PC5 link between the UE and the relay UE configured by the network; or

(2) a specified PC5 relay RLC channel (e.g. a default PC5 relay RLC channel).

[0146] In an implementation, the UE may further receive, from the relay UE, an RRC setup message on SRB0 using "the PC5 relay RLC channel" or "the specified PC5 relay RLC channel".

[0147] In some implementations, discovery message #1 includes at least one of the following:

- (1) information indicating whether to allow a relay UE to access the UE such that the UE can act as a parent relay UE of this relay UE, e.g. information indicating whether to allow a child relay UE to access the UE;
- (2) information indicating whether the UE is an OOC UE or an IC UE with reference to the network node;
- (3) information indicating whether the UE is a single-hop relay UE or a multiple-hop relay UE towards the network node;
- (4) information indicating whether a backhaul (BH) between the UE and the network node is established (i.e., whether the BH has been established already), in response to that the UE is a multiple-hop relay UE towards the network node;
- (5) a total number of hops between the UE and the network node;
- (6) time duration in which the UE can provide service if the UE acts as a multiple-hop relay UE (e.g. acting as a parent or child relay UE);
- (7) information indicating whether there is one or more connected remote UEs, wherein a PC5 connection between one or more connected remote UEs and the UE has been established;
- (8) a total number of the one or more connected remote UEs;
- (9) channel quality of a PC5 link between the UE and the relay UE (e.g. a PC5 link between relay UE #2 and relay UE #1 in Figure 6); or
- (10) channel quality of a Uu link (e.g. Uu RSRP) between the UE and the network node, in response to that the UE is in coverage of the network node (e.g. relay UE #3 in Figure 6).

[0148] It should be noted that the method described in Figure 7 describes possible implementations, and that the operations and the steps may be rearranged or otherwise eliminated or modified and that other implementations are possible, without departing from the spirit and scope of the disclosure.

[0149] Figure 8 illustrates a flowchart of a method related to an L2 U2N relay case in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE (which may act as a parent relay UE) as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions. In some implementations, aspects of operations 802 and 804 may be performed by UE 200 as described with reference to Figure 2. Each of operations 802 and 804 may be performed in accordance with examples as described herein. Specific examples are described in the embodiments of Figures 10-12 as follows.

[0150] At operation 802, the method may include transmitting a discovery message (denoted as discovery message #3) by a relay UE (e.g. relay UE #1 in Figure 6). At operation 804, the method may include establishing a PC5 connection between the relay UE and another relay UE (e.g. relay UE #2 or relay UE #3 in Figure 6). For simplicity, the relay UE is denoted as relay UE #a, and this another relay UE is denoted as relay UE #b. Relay UE #a may act as a parent relay UE. Relay UE #b may act as a child relay UE of relay UE #a. The PC5 connection between relay UE #a and relay UE #b may refer to "PC5 connection #1" as described in the embodiments of Figure 7.

[0151] In operation 804, a connection between relay UE #a and a network node (e.g. BS #1 in Figure 6) has been established, e.g. via a Uu interface. A remote UE (e.g. remote UE #1 or remote UE #2 in Figure 6) is expected to establish an end-to-end connection towards the network node via these two relay UEs, i.e. relay UE #a and relay UE #b. For example, as shown in Figure 6, remote UE #1 is expected to establish an end-to-end connection towards BS #1 via relay UE #2 and relay UE #1. Remote UE #2 is expected to establish an end-to-end connection towards BS #1 via relay UE #3 and relay UE #1.

[0152] The orders of performing operations 802 and 804 may be different in different embodiments. In some embodiments, discovery message #3 is transmitted by relay UE #a (e.g. relay UE #1 in Figure 6) before establishing the PC5 connection between relay UE #a

and relay UE #b. In some other embodiments, discovery message #3 is transmitted by relay UE #a after establishing the PC5 connection between relay UE #a and relay UE #b.

[0153] In some implementations, relay UE #a may receive, from the network node, information indicating whether the network node supports a multiple-hop sidelink L2 relay UE. For example, the network node broadcasts such information via system information (e.g. SIB) or dedicated signaling. A specific example is described in the embodiments of Figure 12 as follows.

[0154] In some implementations, relay UE #a may receive a discovery message (e.g. discovery message #1 as described in the embodiments of Figure 7) from relay UE #b before or after establishing the PC5 connection between relay UE #a and relay UE #b. The information or elements included in discovery message #1 as described in the embodiments of Figure 7 are applicable for the embodiments of Figure 8 here.

[0155] In some implementations, discovery message #1 is received from relay UE #b in response to meeting the following conditions:

- (1) the PC5 connection between relay UE #a and relay UE #b is established;
- (2) an end-to-end connection between relay UE #b and the network node is established; and
- (3) relay UE #b transits to an RRC connected state, an RRC idle state, or an RRC inactive state.

[0156] In some implementations, relay UE #a may receive, from relay UE #b, an RRC setup request message on SRB0 using (1) a PC5 relay RLC channel for a PC5 link between relay UE #b and relay UE #a configured by the network; or (2) a specified PC5 relay RLC channel, e.g. a default PC5 relay RLC channel. In an implementation, relay UE #a may transmit, to relay UE #b, an RRC setup message on SRB0 using the first PC5 relay RLC channel or the specified PC5 relay RLC channel.

[0157] In some implementations, discovery message #3 includes at least one of the following:

- (1) information indicating whether to allow a relay UE to access relay UE #a such that relay UE #a can act as a parent relay UE of this relay UE, e.g. information indicating whether to allow a child relay UE to access relay UE #a;

- (2) information indicating whether relay UE #a is an OOC UE or an IC UE with reference to the network node;
- (3) information indicating whether relay UE #a is a single-hop relay UE or a multiple-hop relay UE towards the network node;
- (4) information indicating whether a backhaul (BH) between relay UE #a and the network node is established, in response to that relay UE #a is a multiple-hop relay UE towards the network node;
- (5) a total number of hops between relay UE #a and the network node;
- (6) time duration in which relay UE #a can provide service if relay UE #a acts as a multiple-hop relay UE;
- (7) information indicating whether there is one or more connected remote UEs wherein a PC5 connection between one or more connected remote UEs and relay UE #a has been established;
- (8) a total number of the one or more connected remote UEs; or
- (9) channel quality of a Uu link between relay UE #a and the network node, in response to that relay UE #a is in coverage of the network node (e.g. relay UE #1 in Figure 6).

[0158] It should be noted that the method described in Figure 8 describes possible implementations, and that the operations and the steps may be rearranged or otherwise eliminated or modified and that other implementations are possible, without departing from the spirit and scope of the disclosure.

[0159] Figure 9 illustrates a flowchart of a method related to an L2 U2N relay case in accordance with aspects of the present disclosure. The operations of the method may be implemented by a network node, e.g. a BS as described herein. In some implementations, the BS may execute a set of instructions to control the function elements of the BS to perform the described functions. In some implementations, aspects of operations 902 and 904 may be performed by NE 400 as described with reference to Figure 4. Each of operations 902 and 904 may be performed in accordance with examples as described herein. Specific examples are described in the embodiments of Figures 10-12 as follows.

[0160] At operation 902, the method may include receiving, by a network node (e.g. BS #1 in Figure 6) from a UE, capability of the UE for supporting a multiple-hop sidelink L2 relay UE. The UE may be:

- (1) a remote UE (e.g. remote UE #1 or remote UE #2 in Figure 6);
- (2) a single-hop relay UE (e.g. relay UE #1 in Figure 6); and/or
- (3) a multiple-hop relay UE (e.g. relay UE #2 or relay UE #3 in Figure 6).

[0161] At operation 904, the method may include transmitting, by the network node, information indicating whether the network node supports the multiple-hop sidelink L2 relay UE.

[0162] In some implementations, the network node may further transmit at least one of the following to the UE, e.g. via system information (e.g. SIB) or dedicated signaling:

- (1) Configuration information regarding a threshold associated with a channel quality of a PC5 link between the UE and a relay UE, e.g. threshold #1 as described in the embodiments of Figure 7.
- (2) Configuration information regarding a threshold associated with a channel quality of a Uu link between the UE and the network node (for example, if the UE is an IC UE), e.g. threshold #2 as described in the embodiments of Figure 7. For example, this threshold may be a minimum Uu RSRP threshold configured by the network node.
- (3) Configuration information (denoted as configuration #1) regarding a PC5 relay RLC channel which is configured for the PC5 link between the UE and the relay UE. Specific examples are described in the embodiments of Figures 10-12 as follows.

[0163] It should be noted that the method described in Figure 9 describes possible implementations, and that the operations and the steps may be rearranged or otherwise eliminated or modified and that other implementations are possible, without departing from the spirit and scope of the disclosure.

[0164] Figure 10 illustrates a schematic diagram of an L2 U2N relay case in accordance with aspects of the present disclosure. Details described in all other embodiments of the present disclosure are applicable for the embodiments shown in Figure 10.

[0165] In the exemplary flowchart 1000 as shown in Figure 10, in operation 1011, UE 1002 (which is to be act as a child relay UE) (e.g. relay UE #2 in Figure 6) may transmit a relay discovery message (e.g. discovery message #1 as described in the embodiments of Figure 7) and may monitor a relay discovery message (e.g. discovery message #2 as described in the embodiments of Figure 7) from a remote UE (e.g. UE 1001) on a sidelink between UE 1001 and UE 1002. Different operations may be performed in operation 1011 according to different embodiments, e.g. Option #1 and Option #2 as below.

[0166] Option #1: There is a threshold (e.g. threshold #1) for a PC5 link between UE 1002 towards a parent relay UE1003. In some embodiments, when UE 1002 is out of coverage of BS 1004 (e.g. BS #1 in Figure 6) (i.e. UE 1002 is an OOC UE), this threshold is a pre-configured threshold. In some embodiments, after UE 1002 transits to an RRC connected state or an RRC idle state or an RRC inactive state, BS 1004 (e.g. gNB) can transmit or configure this threshold to UE 1002 via broadcast signalling or dedicated signalling.

[0167] In Option #1, if a channel quality of a PC5 link between UE 1002 and parent relay UE 1003 is greater than or equal to the threshold (e.g. threshold #1), UE 1002 can act as a child relay UE. Then, child relay UE 1002 is allowed to transmit or monitor a discovery message from other UEs. In Option #1, child relay UE 1002 (e.g. which is out of coverage of BS 1004) can transmit a discovery message before connecting BS 1004. Once a remote UE (e.g. remote UE 1001) selects child relay UE 1002, child relay UE 1002 will be triggered to establish a connection towards the network node.

[0168] Option #2: UE 1002 (to be act as a child relay UE) has established a PC5 connection towards parent relay UE 1003. Then, child relay UE 1002 is allowed to transmit a relay discovery message, e.g. towards remote UE 1001, and may monitor a relay discovery message, e.g. from remote UE 1001 over a sidelink. In Option #2, if a PC5 connection between child relay UE 1002 (e.g. e.g. which is out of coverage of BS 1004) and parent relay UE 1003 has been established, child relay UE 1002 is allowed to transmit the discovery message.

[0169] In operation 1011 (e.g. Option #1 or Option #2), at least one of the following information can be included in the discovery message broadcasted by UE 1002:

- (1) information indicating whether to allow a relay UE to access UE 1002 such that UE 1002 can act as a parent relay UE of this relay UE, e.g. information indicating whether to allow a child relay UE to access UE 1002;
- (2) information indicating whether UE 1002 is an OOC UE or an IC UE with reference to BS 1004;
- (3) information indicating whether UE 1002 is a single-hop relay UE or a multiple-hop relay UE towards BS 1004;
- (4) information indicating whether a backhaul (BH) between UE 1002 and BS 1004 is established, in response to that UE 1002 is a multiple-hop relay UE;
- (5) a total number of hops between UE 1002 and BS 1004;
- (6) time duration in which UE 1002 can provide service if UE 1002 acts as a multiple-hop relay UE;
- (7) information indicating whether there is one or more connected remote UEs, wherein a PC5 connection between these connected remote UEs and UE 1002 has been established;
- (8) a total number of the one or more connected remote UEs;
- (9) channel quality of a PC5 link between UE 1002 and its parent relay UE 1003 (e.g. a PC5 link between relay UE #2 and relay UE #1 in Figure 6); or
- (10) channel quality of a Uu link (e.g. Uu RSRP) between UE 1002 and BS 1004, if UE 1002 is in coverage of BS 1004 (e.g. relay UE #3 in Figure 6).

[0170] In some embodiments, if UE 1002 is in coverage of BS 1004, UE 1002 may receive, from BS 1004, information indicating whether BS 1004 supports the multiple-hop sidelink L2 relay UE, e.g. via system information or dedicated signaling. In some other embodiments, if UE 1002 is out of coverage of BS 1004 while an end-to-end connection between UE 1002 and BS 1004 via a parent relay UE 1003 is established, UE 1002 may receive such information from BS 1004 via parent relay UE 1003, e.g. via system information or dedicated signaling. For instance, if system information is used, BS 1004 may transmit such information via SIB as follows:

Multi-hop-sl-L2U2N-Relay-r17

ENUMERATED {enabled}

Two-hop-sl-L2U2N-Relay-r17

ENUMERATED {enabled}

[0171] In operation 1012, UE 1001 (i.e. a remote UE out of coverage of BS 1004) receives the discovery message sent by UE 1002, and may select UE 1002 as a child relay UE. For instance, if remote UE 1001 receives two or more discovery messages from child relay UE 1002 or other relay UEs, remote UE 1001 may select child relay UE 1002 as its relay UE towards BS 1004.

[0172] In operation 1013, a PC5 connection between remote UE 1001 and child relay UE 1002 is established based on a NR sidelink PC5 unicast link establishment procedure.

[0173] In operation 1014, remote UE 1001 may transmit an RRC message (denoted as message #1), e.g. a SRB0 message, for its connection establishment with BS 1004 via child relay UE 1002 and parent relay UE 1003.

[0174] In some embodiments of operation 1014, remote UE 1001 sends message #1 (i.e., an RRC setup request message) for its connection establishment with BS 1004 to child relay UE 1002 using a specified PC5 relay RLC channel (e.g. a default PC5 relay RLC channel). After receiving message #1 from remote UE 1001, child relay UE 1002 may transmit message #1 to BS 1004 via one of "a configured PC5 relay RLC channel" and "a specified PC5 Relay RLC channel (e.g. a default PC5 Relay RLC channel)". For instance, there may be different embodiments, e.g. Option #A and Option #B as below.

[0175] Option #A: In some implementations, child relay UE 1002 may transmit message #1 (e.g. the RRC setup request message) for connection establishment with BS 1004 (which is received from remote UE 1001) to parent relay UE 1003 via a specified PC5 relay RLC channel over a PC5 link between child relay UE 1002 and parent relay UE 1003. Then, parent relay UE 1003 transmit message #1 to BS 1004 via a specified Uu relay RLC channel over a Uu link between parent relay UE 1003 and BS 1004.

[0176] Option #B: in some implementations, if child relay UE 1002 is not in an RRC state or is not connected to BS 1004, it needs to establish its end-to-end RRC connection with BS 1004 via parent relay UE 1003 upon reception of a message (e.g. message #1) on the specified PC5 relay RLC channel between child relay UE 1002 and remote UE 1001. For instance, child relay UE 1002 may transmit an RRC message (denoted as message #2) (e.g. an RRC setup request message) for connection establishment with BS 1004 via a specified

PC5 relay RLC channel between child relay UE 1002 and parent relay UE 1003. Then, parent relay UE 1003 may transmit message #2 to BS 1004 via a specified Uu relay RLC channel over a Uu link between parent relay UE 1003 and BS 1004. After receiving message #2, BS 1004 may configure a PC5 relay RLC channel for the PC5 link between child relay UE 1002 and parent relay UE 1003. For example, BS 1004 may transmit the corresponding configuration information (e.g. configuration #1 as described in Figure 9) to child relay UE 1002 via parent relay UE 1003. Then, child relay UE 1002 may forward message #1, i.e. the SRB0 message received from remote UE 1001 (e.g. the RRC setup request message), to BS 1004 via one of "the configured PC5 relay RLC channel" and "the specified PC5 Relay RLC channel (e.g. a default PC5 Relay RLC channel)" between child relay UE 1002 and parent relay UE 1003.

[0177] In some embodiments of Option #B, if parent relay UE 1003 is not in an RRC_CONNECTED state, it needs to do its own Uu RRC connection establishment upon reception of a message (e.g. message #2) on the specified PC5 relay RLC channel between child relay UE 1002 and parent relay UE 1003. After completing an RRC connection establishment procedure of parent relay UE 1003, BS 1004 may configure a SRB0 relaying Uu Relay RLC channel to parent relay UE 1003. In some embodiments, parent relay UE 1003 may transmit a discovery message (e.g. discovery message #3 as described in the embodiments of Figure 8), e.g. before allowing UE 1002 to access to parent relay UE 1003 to act as a child relay UE.

[0178] In operation 1015, BS 1004 may respond with an RRC setup message to remote UE 1001. In some embodiments, BS 1004 may send the RRC setup message to parent relay UE 1003 using the SRB0 relaying Uu relay RLC channel (e.g. configured by BS 1004) over a Uu link between BS 1004 and parent relay UE 1003. Then, parent relay UE 1003 may send the RRC setup message to child relay UE 1002 using a configured PC5 relay RLC channel (configured by BS 1004) or a specified PC5 relay RLC channel over the PC5 link between child relay UE 1002 and parent relay UE 1003. After that, child relay UE 1002 may send the RRC setup message to remote UE 1001 using the specified PC5 relay RLC channel over the PC5 link between child relay UE 1002 and remote UE 1001.

[0179] In operation 1016, remote UE 1001 can transmit data to BS 1004 or receive data from BS 1004 via an end-to-end RRC connection.

[0180] Figure 11 illustrates a schematic diagram of an L2 U2N relay case in accordance with aspects of the present disclosure. Details described in all other embodiments of the present disclosure are applicable for the embodiments shown in Figure 11.

[0181] In the exemplary flowchart 1100 as shown in Figure 11, in operation 111, UE 1102 (which is to act as a child relay UE) (e.g. relay UE #2 or relay UE #3 in Figure 6) may transmit a relay discovery message (e.g. discovery message #1 as described in the embodiments of Figure 7) and may monitor a relay discovery message (e.g. discovery message #2 as described in the embodiments of Figure 7) from a remote UE (e.g. UE 1101) on a sidelink between UE 1101 and UE 1102.

[0182] In some embodiments of operation 111, if UE 1102 transits to an RRC connected state (or an RRC idle state or an RRC inactive state), UE 1102 is allowed to transmit the discovery message. That is, the condition for UE 1102 acting as a child relay UE is that UE 1102 transits to an RRC connected state or an RRC idle state or an RRC inactive state. For example, if a PC5 connection between UE 1102 (i.e. child relay UE 1102) and UE 1103 (i.e. parent relay UE 1103) is established, if an end-to-end connection between child relay UE 1102 and BS 1104 is established, and if child relay UE 1102 transits to one of "an RRC connected state, an RRC idle state, and an RRC inactive state", child relay UE 1102 is allowed to transmit the discovery message.

[0183] In some implementations, if child relay UE 1102 is in an RRC connected state, the PC5 relay RLC channel for a PC5 link between child relay UE 1102 and parent relay UE 1103 may be configured by BS 1104 for a SRB0 message received from remote UE 1101 (e.g. an RRC setup request message). Details are described in Option #Y as below.

[0184] In operation 111, at least one of the following information can be included in the discovery message broadcasted by UE 1102:

- (1) information indicating whether to allow a relay UE to access UE 1102 such that UE 1102 can act as a parent relay UE of this relay UE, e.g. information indicating whether to allow a child relay UE to access UE 1102;
- (2) information indicating whether UE 1102 is an OOC UE or an IC UE with reference to BS 1104;

- (3) information indicating whether UE 1102 is a single-hop relay UE or a multiple-hop relay UE towards BS 1104;
- (4) information indicating whether a backhaul (BH) between UE 1102 and BS 1104 is established, in response to that UE 1102 is a multiple-hop relay UE;
- (5) a total number of hops between UE 1102 and BS 1104;
- (6) time duration in which UE 1102 can provide service if UE 1102 acts as a multiple-hop relay UE;
- (7) information indicating whether there is one or more connected remote UEs, a PC5 connection between which and UE 1102 is established;
- (8) a total number of the one or more connected remote UEs;
- (9) channel quality of a PC5 link between UE 1102 and parent relay UE 1103 (e.g. a PC5 link between relay UE #2 and relay UE #1 in Figure 6); or
- (10) channel quality of a Uu link (e.g. Uu RSRP value) between UE 1102 and BS 1104, if UE 1102 is in coverage of BS 1104 (e.g. relay UE #3 in Figure 6).

[0185] In some embodiments, if UE 1102 is in coverage of BS 1104, UE 1102 may receive, from BS 1104, information indicating whether BS 1104 supports the multiple-hop sidelink L2 relay UE, e.g. via system information or dedicated signaling. In some other embodiments, if UE 1102 is out of coverage of BS 1104 while an end-to-end RRC connection between UE 1102 and BS 1104 via a parent relay UE 1103 is established, UE 1102 may receive such information from BS 1104 via parent relay UE 1103, e.g. via system information or dedicated signaling. For instance, if system information is used, BS 1104 may transmit such information via SIB as follows:

Multi-hop-sl-L2U2N-Relay-r17	ENUMERATED {enabled}
Two-hop-sl-L2U2N-Relay-r17	ENUMERATED {enabled}

[0186] In operation 112, UE 1101 (i.e. a remote UE out of coverage of BS 1104) receives the discovery message sent by UE 1102, and may select UE 1102 as a child relay UE. For instance, if remote UE 1101 receives two or more discovery messages from child relay UE

1102 or other relay UEs, remote UE 1101 may select child relay UE 1102 as its relay UE towards BS 1104.

[0187] In operation 113, a PC5 connection between remote UE 1101 and child relay UE 1102 is established based on a NR sidelink PC5 unicast link establishment procedure.

[0188] In operation 114, remote UE 1101 may transmit an RRC message (denoted as message #a), e.g. a SRB0 message, for its connection establishment with BS 1104 via child relay UE 1102 and parent relay UE 1103.

[0189] In some embodiments of operation 114, remote UE 1101 sends message #a (i.e., an RRC setup request message) for its connection establishment with BS 1104 to child relay UE 1102 using a specified PC5 relay RLC channel (e.g. a default PC5 relay RLC channel). After receiving message #a from remote UE 1101, child relay UE 1102 may transmit message #a to BS 1104 via one of "a configured PC5 relay RLC channel" and "a specified PC5 Relay RLC channel (e.g. a default PC5 Relay RLC channel)". For instance, there may be different embodiments, e.g. Option #X and Option #Y as below.

[0190] Option #X: In some implementations, child relay UE 1102 may transmit message #a (e.g. the RRC setup request message) for connection establishment with BS 1104 (which is received from remote UE 1101) to parent relay UE 1103 via a specified PC5 relay RLC channel over a PC5 link between child relay UE 1102 and parent relay UE 1103. Then, parent relay UE 1103 transmit message #a to BS 1104 via a specified Uu relay RLC channel over a Uu link between parent relay UE 1103 and BS 1104.

[0191] Option #Y: in some implementations, if child relay UE 1102 is not in an RRC state or is not connected to BS 1104, it needs to establish its end-to-end RRC connection with BS 1104 via parent relay UE 1103 upon reception of a message (e.g. message #a) on the specified PC5 relay RLC channel, e.g. from remote UE 1101. For instance, child relay UE 1102 may transmit an RRC message (denoted as message #b) (e.g. an RRC setup request message) for connection establishment with BS 1104 via a specified PC5 relay RLC channel between child relay UE 1102 and parent relay UE 1103. Then, parent relay UE 1103 transmit message #b to BS 1104 via a specified Uu relay RLC channel over a Uu link between parent relay UE 1103 and BS 1104. After receiving message #b, BS 1104 may configure a PC5 relay RLC channel for the PC5 link between child relay UE 1102 and parent relay UE 1103.

For example, BS 1104 may transmit the corresponding configuration information (e.g. configuration #1 as described in Figure 9) to child relay UE 1102 via parent relay UE 1103. Then, child relay UE 1102 may forward message #a, i.e. the SRB0 message received from remote UE 1101 (e.g. the RRC setup request message), to BS 1104 via "the configured PC5 relay RLC channel" or "the specified PC5 Relay RLC channel (e.g. a default PC5 Relay RLC channel)" between child relay UE 1102 and parent relay UE 1103.

[0192] In some embodiments of Option #Y, if parent relay UE 1103 is not in an RRC_CONNECTED state, it needs to do its own Uu RRC connection establishment upon reception of a message (e.g. message #a or message #b) from child relay UE 1102 on the specified PC5 relay RLC channel between child relay UE 1102 and parent relay UE 1103. After completing an RRC connection establishment procedure of parent relay UE 1103, BS 1104 may configure a SRB0 relaying Uu relay RLC channel to parent relay UE 1103. In some embodiments, parent relay UE 1103 may transmit a discovery message (e.g. discovery message #3 as described in the embodiments of Figure 8), e.g. before allowing UE 1102 to access to parent relay UE 1103 to act as a child relay UE.

[0193] In operation 115, BS 1104 may respond with an RRC setup message to remote UE 1101. In some embodiments, BS 1104 may send the RRC setup message to parent relay UE 1103 using a SRB0 relaying Uu relay RLC channel (e.g. configured by BS 1104) over a Uu link between BS 1104 and parent relay UE 1103. Then, parent relay UE 1103 may send the RRC setup message to child relay UE 1102 using the configured PC5 relay RLC channel (configured by BS 1104) or the specified PC5 relay RLC channel over the PC5 link between child relay UE 1102 and parent relay UE 1103. After that, child relay UE 1102 may send the RRC setup message to remote UE 1101 using the specified PC5 relay RLC channel over the PC5 link between child relay UE 1102 and remote UE 1101.

[0194] In operation 116, remote UE 1101 can transmit data to BS 1104 or receive data from BS 1104 via an end-to-end RRC connection.

[0195] Figure 12 illustrates a schematic diagram of an L2 U2N relay case in accordance with aspects of the present disclosure. Details described in all other embodiments of the present disclosure are applicable for the embodiments shown in Figure 12.

[0196] In the exemplary flowchart 1200 as shown in Figure 12, in operation 121, UE 1202 accesses the serving BS 1204 (e.g. gNB) via Uu interface. UE 1202 is in coverage of BS 1204. That is, UE 1202 is an IC UE (e.g. relay UE #3 in Figure 6). For instance, UE 1202 may report one or more measurement results based on configuration information from BS 1204. The measurement results may include measurement results for the cell or for a candidate relay UE.

[0197] In some embodiments, UE 1202 receives the configuration related to multi-hop relay from BS 1204. BS 1204 may transmit information indicating whether to support multi-hop L2 U2N relay (or child L2 U2N relay) via system information (e.g. SIB) or dedicated signalling. If the system information is used, BS 1204 may transmit such information via SIB as follows.

Multi-hop-sl-L2U2N-Relay-r17	ENUMERATED {enabled}
Two-hop-sl-L2U2N-Relay-r17	ENUMERATED {enabled}

[0198] In some embodiments, BS 1204 may transmit a threshold (e.g. threshold #2 as described in the embodiments of Figure 7) of Uu channel quality via system information (e.g. SIB) or dedicated signaling. For instance, this threshold could be "a minimum Uu RSRP threshold" used for a UE acting as a L2 relay UE. If a channel quality of the Uu channel between UE 1202 and BS 1204 is less than or equal to the threshold, UE 1202 is allowed to act as "a child L2 relay UE", i.e. child relay 1202 (e.g. relay UE #3 in Figure 6), i.e. the condition for acting as a child relay UE is met. That is, UE 1202 needs to connect with BS 1204 via a parent relay UE (e.g. relay UE #1 in Figure 6). In some embodiments, parent relay UE 1203 may transmit a discovery message (e.g. discovery message #3 as described in the embodiments of Figure 8), e.g. before allowing UE 1202 to access to parent relay UE 1203 to act as a child relay UE.

[0199] In operation 122, child relay UE 1202 is allowed to transmit a discovery message (e.g. discovery message #1 as described in the embodiments of Figure 7) and monitor a discovery message (e.g. discovery message #2 as described in the embodiments of Figure 7) based on any of the following conditions, i.e. Condition #1, Condition #2, and Condition #3.

[0200] Condition #1: the condition for acting as a child relay UE is met (e.g. a channel quality of the Uu channel between UE 1202 and BS 1204 is less than or equal to threshold

#2), and a channel quality of a PC5 link between child relay UE 1202 and parent relay UE 1203 is greater than or equal to a threshold (e.g. threshold #3 as described in the embodiments of Figure 7). A PC5 connection between child relay UE 1202 and parent relay UE 1203 is not established yet. That is, child relay UE 1202 is allowed to transmit a discovery message and monitor a discovery message when meeting Condition #1, while the PC5 connection between child relay UE 1202 and parent relay UE 1203 does not need to be established.

[0201] Condition #2: the condition for acting as a child relay UE is met (e.g. a channel quality of the Uu channel between UE 1202 and BS 1204 is less than or equal to threshold #2), a channel quality a PC5 link between child relay UE 1202 and parent relay UE 1203 is greater than or equal to a threshold (e.g. threshold #3 as described in the embodiments of Figure 7), and a PC5 connection between child relay UE 1202 and parent relay UE 1203 is established already. But child relay UE 1202 connects to BS 1204 via Uu interface. That is, child relay UE 1202 is allowed to transmit a discovery message and monitor a discovery message when meeting Condition #2, while an end-to-end connection between child relay UE 1202 and BS 1204 does not need to be established.

[0202] Condition #3: child relay UE 1202 connects to BS 1204 via parent relay UE 1203. Namely, the end-to-end connection between child relay UE 1202 and BS 1204 has been established. That is, child relay UE 1202 is allowed to transmit a discovery message and monitor a discovery message when meeting Condition #3, wherein the end-to-end connection between child relay UE 1202 and BS 1204 is established. After meeting Condition #3, child relay UE 1202 may be in one of: an RRC_CONNECTED state, RRC_IDLE state, or RRC_INACTIVE state.

[0203] In operation 123, remote UE 1201 receives the discovery message sent by child relay UE 1202 and may select UE 1202 as a child relay UE. For example, if remote UE 1201 receives two or more discovery messages from child relay UE 1202 or other relay UEs, remote UE 1201 may select UE 1202 as the child relay UE.

[0204] In operation 124, a PC5 connection between remote UE 1201 and child relay UE 1202 is established based on a NR sidelink PC5 unicast link establishment procedure.

[0205] In operation 125, remote UE 1201 may transmit an RRC message (denoted as message #x), e.g. a SRB0 message, for its connection establishment with BS 1204 via child relay UE 1202 and parent relay UE 1203.

[0206] In some embodiments of operation 125, remote UE 1201 sends message #x (i.e., an RRC setup request message) for its connection establishment with BS 1204 to child relay UE 1202 using a specified PC5 relay RLC channel (e.g. a default PC5 relay RLC channel). After receiving message #x from remote UE 1201, child relay UE 1202 may transmit message #x to BS 1204 via one of "a configured PC5 relay RLC channel" and "a specified PC5 Relay RLC channel (e.g. a default PC5 Relay RLC channel)". For instance, there may be different embodiments, e.g. Option #M and Option #N as below.

[0207] Option #M: In some implementations, child relay UE 1202 may transmit message #x (e.g. the RRC setup request message) for connection establishment with BS 1204 (which is received from remote UE 1201) to parent relay UE 1203 via a specified PC5 relay RLC channel over a PC5 link between child relay UE 1202 and parent relay UE 1203. Then, parent relay UE 1203 transmit message #x to BS 1204 via a specified Uu relay RLC channel over a Uu link between parent relay UE 1203 and BS 1204.

[0208] Option #N: in some implementations, if child relay UE 1202 is not in an RRC state or is not connected to BS 1204, it needs to establish its end-to-end RRC connection with BS 1204 via parent relay UE 1203 upon reception of a message (e.g. message #x) on the specified PC5 relay RLC channel, e.g. from remote UE 1201. For instance, child relay UE 1202 may transmit an RRC message (denoted as message #y) (e.g. an RRC setup request message) for connection establishment with BS 1204 via a specified PC5 relay RLC channel between child relay UE 1202 and parent relay UE 1203. Then, parent relay UE 1203 transmit message #y to BS 1204 via a specified Uu relay RLC channel over a Uu link between parent relay UE 1203 and BS 1204. After receiving message #y, BS 1204 may configure a PC5 relay RLC channel for the PC5 link between child relay UE 1202 and parent relay UE 1203. For example, BS 1204 may transmit the corresponding configuration information (e.g. configuration #1 as described in Figure 9) to child relay UE 1202 via parent relay UE 1203. Then, child relay UE 1202 may forward message #x, i.e. the SRB0 message received from remote UE 1201 (e.g. the RRC setup request message), to BS 1204 via "the configured PC5

relay RLC channel" or "the specified PC5 Relay RLC channel (e.g. a default PC5 Relay RLC channel)" between child relay UE 1202 and parent relay UE 1203.

[0209] In some embodiments of Option #N, if parent relay UE 1203 is not in an RRC_CONNECTED state, it needs to do its own Uu RRC connection establishment upon reception of a message (e.g. message #x or message #y) from child relay UE 1202 on the specified PC5 relay RLC channel between child relay UE 1202 and parent relay UE 1203. After completing an RRC connection establishment procedure of parent relay UE 1203, BS 1204 may configure a SRB0 relaying Uu relay RLC channel to parent relay UE 1203.

[0210] In operation 126, BS 1204 may respond with an RRC setup message to remote UE 1201. In some embodiments, BS 1204 may send the RRC setup message to parent relay UE 1203 using a SRB0 relaying Uu relay RLC channel (e.g. configured by BS 1204) over a Uu link between BS 1204 and parent relay UE 1203. Then, parent relay UE 1203 may send the RRC setup message to child relay UE 1202 using the configured PC5 relay RLC channel (configured by BS 1204) or the specified PC5 relay RLC channel over the PC5 link between child relay UE 1202 and parent relay UE 1203. After that, child relay UE 1202 may send the RRC setup message to remote UE 1201 using the specified PC5 relay RLC channel over the PC5 link between child relay UE 1202 and remote UE 1201.

[0211] In operation 127, remote UE 1201 can transmit data to BS 1204 or receive data from BS 1204 via an end-to-end RRC connection.

[0212] 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:

1. A first user equipment (UE), comprising:
 - at least one memory; and
 - at least one processor coupled to the at least one memory and configured to cause the first UE to:
 - transmit a discovery message; and
 - establish a first PC5 connection between the first UE and a first relay UE and
 - establish a second PC5 connection between the first UE and a remote UE,
 - wherein a connection between the first relay UE and a network node is established,
 - and
 - wherein the remote UE is expected to establish an end-to-end connection towards the network node via both the first UE and the first relay UE.
2. The first UE of Claim 1, wherein the processor of the first UE is configured to receive, from the network node, first information indicating whether the network node supports a multiple-hop sidelink layer 2 (L2) relay UE.
3. The first UE of Claim 1, wherein the processor of the first UE is configured to:
 - determine whether a channel quality of a PC5 link between the first UE and the first relay UE is greater than or equal to a first threshold; and
 - in response to that the channel quality of the PC5 link between the first UE and the first relay UE is greater than or equal to the first threshold, determine that the first UE can act as a multiple-hop relay UE.
4. The first UE of Claim 3, in response to that the first UE can act as the multiple-hop relay UE, the first UE is allowed to transmit the discovery message or monitor another discovery message before establishing the first PC5 connection.
5. The first UE of Claim 4, wherein the processor of the first UE is configured to:
 - in response to that a PC5 link between the remote UE and the first UE is established after the first UE transmitting the discovery message, trigger to establish an end-to-end connection between the first UE and the network node.
6. The first UE of Claim 3, wherein the first threshold is a pre-configured threshold.

7. The first UE of Claim 1, in response to that the first PC5 connection is established, the first UE is allowed to transmit the discovery message.
8. The first UE of Claim 1, in response to that the first PC5 connection is established and an end-to-end connection between the first UE and the network node is established, the first UE is allowed to transmit the discovery message.
9. The first UE of Claim 1, wherein the processor of the first UE is configured to:
 - determine whether a channel quality of a Uu link between the first UE and the network node is less than or equal to a second threshold; and
 - in response to that the channel quality of the Uu link between the first UE and the network node is less than or equal to the second threshold, determine that the first UE can act as a multiple-hop relay UE.
10. The first UE of Claim 9, in response to that the first UE can act as the multiple-hop relay UE, the processor of the first UE is configured to:
 - determine whether a channel quality of a PC5 link between the first UE and the first relay UE is greater than or equal to a third threshold; and
 - in response to that the channel quality of the PC5 link between the first UE and the first relay UE is greater than or equal to the third threshold, the first UE is allowed to transmit the discovery message before establishing the first PC5 connection.
11. The first UE of Claim 9 or Claim 10, wherein the processor of the first UE is configured to receive, from the network node, first configuration information including the second threshold, the third threshold, or a combination thereof.
12. The first UE of Claim 2 or Claim 11, wherein the first information, the first configuration information, or a combination thereof is received by the first UE from the network node via system information or dedicated signaling.
13. The first UE of Claim 9, in response to that the first UE can act as the multiple-hop relay UE, the first UE is allowed to transmit the discovery message in response to meeting one of the following conditions:
 - the first PC5 connection is established and before establishing an end-to-end connection between the first UE and the network node;

the end-to-end connection between the first UE and the network node is established;
or

the first UE is configured to transit to an RRC connected state, an RRC idle state or an RRC inactive state.

14. The first UE of any of Claims 2-13, wherein the processor of the first UE is configured to:

receive an RRC setup request message from the remote UE; and
transmit, to the first relay UE, the RRC setup request message on a signaling radio bearer (SRB) 0 using one of the following:

a first PC5 relay radio link control (RLC) channel for the PC5 link between the first UE and the first relay UE configured by the network; and
a specified PC5 relay RLC channel.

15. The first UE of Claim 14, wherein the processor of the first UE is configured to:

receive, from the first relay UE, an RRC setup message on the SRB 0 using one of the following:

the first PC5 relay RLC channel; and
the specified PC5 relay RLC channel.

16. The first UE of any of Claims 1-15, wherein the discovery message includes:

information indicating whether to allow a relay UE to access the first UE such that the first UE can act as a parent relay UE of the relay UE;

information indicating whether the first UE is an out of coverage (OOC) UE or an in-coverage (IC) UE with reference to the network node;

information indicating whether the first UE is a single-hop relay UE or a multiple-hop relay UE towards the network node;

information indicating whether a backhaul (BH) between the first UE and the network node is established, in response to that the first UE is the multiple-hop relay UE towards the network node;

a total number of hops between the first UE and the network node;

time duration in which the first UE can provide service if the first UE acts as the multiple-hop relay UE;

information indicating whether there is one or more connected remote UEs a PC5 connection between which and the first UE is established;
a total number of the one or more connected remote UEs;
channel quality of a PC5 link between the first UE and the first relay UE;
channel quality of a Uu link between the first UE and the network node, in response to that the first UE is in coverage of the network node;
or a combination thereof.

17. A first relay user equipment (UE), comprising:
 - at least one memory; and
 - at least one processor coupled to the at least one memory and configured to cause the first relay UE to:
 - transmit a first discovery message; and
 - establish a first PC5 connection between the first relay UE and a second relay UE, wherein a connection between the first relay UE and a network node is established, and
 - wherein a remote UE is expected to establish an end-to-end connection towards the network node via both the second relay UE and the first relay UE.
18. The first relay UE of Claim 17, wherein the processor of the first relay UE is configured to receive, from the network node, first information indicating whether the network node supports a multiple-hop sidelink layer 2 (L2) relay UE.
19. A network node, comprising:
 - at least one memory; and
 - at least one processor coupled to the at least one memory and configured to cause the network node to:
 - receive, from a user equipment (UE), capability of the UE for supporting a multiple-hop sidelink layer 2 (L2) relay UE; and
 - transmit information indicating whether the network node supports the multiple-hop sidelink L2 relay UE.
20. The network node of Claim 19, wherein the processor of the network node is configured to transmit at least one of the following to the UE:

first configuration information regarding a first threshold associated with a channel quality of a PC5 link between the UE and a first relay UE;

second configuration information regarding a second threshold associated with a channel quality of a Uu link between the UE and the network node; or

third configuration information regarding a PC5 relay radio link control (RLC) channel configured for the PC5 link between the UE and the first relay UE.