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### Packet routing for layer-2-based sidelink relay

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#### Abstract

Apparatus and methods are provided for L2-based sidelink relay for packet routing. In novel aspect, the L2-based sidelink relay for packet routing is configured based on interest indications from one or more candidate UEs and corresponding UE report from candidate UEs. In one embodiment, the UE report is received from an Uu interface RRC message or an RRC message forwarded through an Xn interface from a serving gNB. The L2 relay configuration includes one or more elements comprising an adaptation layer address of nodes in the relay path, and a packet routing table. The adaption layer is between an RRC layer and a PDCP layer. The packet routing table includes one or more elements including adaptation layer addresses, a relay path ID, and a next hop address. In one embodiment, the relay path includes one or more relay hops.

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## Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This application is filed under 35 U.S.C. § 111(a) and is based on and hereby claims priority under 35 U.S.C. § 120 and § 365(c) from International Application No. PCT/CN2019/120250, titled “Methods and Apparatus of Packet Routing for Sidelink Relay,” with an international filing date of Nov. 22, 2019. This application claims priority under 35 U.S.C. § 119 from Chinese Application Number CN 202011255294.4 titled “PACKET ROUTING FOR LAYER-2-BASED SIDELINK RELAY” filed on Nov. 11, 2020. The disclosure of each of the foregoing documents is incorporated herein by reference.

## TECHNICAL FIELD

(1) The disclosed embodiments relate generally to wireless communication, and, more particularly, to packet routing for layer-2-based sidelink relay.

## BACKGROUND

(2) 5G radio access technology will be a key component of the modern access network. It will address high traffic growth and increasing demand for high-bandwidth connectivity. Wireless relay in cellular networks provides extended coverage and improved transmission reliability. Long term evolution (LTE) network introduced 3GPP sidelink, the direct communication between two user equipment (UEs) without signal relay through a base station. In 3GPP New Radio (NR), sidelink continues evolving. With new functionalities supported, the sidelink offers low latency, high reliability and high throughput for device to device communications. Using sidelink for wireless relay provides a reliable and efficient way for traffic forwarding. For the early sidelink-based wireless relay services, such as the ProSe UE-to-Network relay, the traffic between the remote UE and the base station is forwarded at the IP layer by the relay UE. The relay operation was specified for LTE aiming at coverage expansion from the perspective of Layer-3 (L3) relay. The Layer-2 (L2) based relay using sidelink can improve the efficiency and flexibility.

(3) Improvements and enhancements are required for packet routing using sidelink in the wireless network.

## SUMMARY

(4) Apparatus and methods are provided for L2-based sidelink relay for packet routing. In novel aspect, the L2-based sidelink relay for packet routing is configured based on indications from one or more candidate UEs and corresponding UE report from candidate UEs. In one embodiment, the relay UE obtains relay configuration, configures an L2 packet routing to a remote UE for L2-based packet relay using a first sidelink of the relay UE based on the L2 relay configuration, wherein an L2 relay path is established for the remote UE using the first sidelink, performs packet data relay to and from the remote UE based on the configured L2 packet routing and releases the configured L2 packet routing upon detecting one or more releasing triggering events. In one embodiment, the L2 relay configuration is generated by a first base station in the wireless network, and wherein the L2 relay configuration is based on UE information reports from a plurality of UE candidates for establishing the L2 relay path. In another embodiment, the L2 relay configuration is generated by a first base station in the wireless network, and wherein the L2 relay configuration is based on UE information reports from a plurality of UE candidates for establishing the L2 relay path. In one embodiment, the first base station receives an UE information report of a candidate UE by one receiving route comprising an Uu interface RRC message from the candidate UE and an RRC message forwarded to the first base station through an Xn interface from a second base station. In

yet another embodiment, the relay UE obtains the L2 relay configuration by one receiving route comprising from the first base station, from an Uu interface RRC message and from a second base station, an RRC message forwarded from the first base station through an Xn interface to the second base station. In one embodiment, the L2 relay configuration includes one or more elements comprising an adaptation layer address of nodes in the relay path, and a packet routing table, wherein the adaption layer is between an RLC layer and a PDCP layer. In another embodiment, the packet routing table includes one or more routing elements comprising one or more adaptation layer addresses, a relay path identification (ID), and a next hop address. In yet another embodiment, the relay path includes one or more relay hops. In one embodiment, the relay UE receives an updated L2 relay configuration, wherein the updated L2 relay configuration is triggered by one or more updated UE information reports from one or more candidate UEs and updates the L2 packet routing to the remote UE based on the updated L2 relay configuration.

(5) In one embodiment, a UE obtains an L2 relay configuration in a wireless network, configures an L2 packet routing for L2-based packet relay using a sidelink between the UE and a first relay UE based on the L2 relay configuration, wherein an L2 relay path is established for the UE using the sidelink, performs packet data transmission and reception to and from an end-node based on the configured L2 packet routing, and releases the configured L2 packet routing upon detecting one or more releasing triggering events.

(6) This summary does not purport to define the invention. The invention is defined by the claims.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) The accompanying drawings, where like numerals indicate like components, illustrate embodiments of the invention.

(2) FIG. 1 is a schematic system diagram illustrating an exemplary wireless network for layer-2 (L2)-based sidelink relay in accordance with embodiments of the current invention.

(3) FIG. 2 illustrates an exemplary NR wireless system with centralized upper layers of the NR radio interface stacks in accordance with embodiments of the current invention.

(4) FIG. 3 illustrates simplified block diagrams of a base station and a mobile device/UE for L2-based sidelink relay in accordance with embodiments of the current invention.

(5) FIG. 4 illustrates exemplary diagrams for a L2-based UE-to-Network relay using sidelink in accordance with embodiments of the current invention.

(6) FIG. 5 illustrates exemplary diagrams for a L2-based UE-to-UE relay using sidelink in accordance with embodiments of the current invention.

(7) FIG. 6 illustrates exemplary diagrams of the user plane protocol stacks for packet routing of L2-based sidelink relay in accordance with embodiments of the current invention.

(8) FIG. 7 illustrates exemplary diagrams of the control plane protocol stacks for packet routing of L2-based sidelink relay in accordance with embodiments of the current invention.

(9) FIG. 8 illustrates exemplary flow diagrams of establishing the L2-based packet routing for sidelink relay in accordance with embodiments of the current invention.

(10) FIG. 9 illustrates exemplary flow diagrams of updating the L2-based packet routing for sidelink relay in accordance with embodiments of the current invention.

(11) FIG. 10 illustrates exemplary flow diagrams of the release procedure for the L2-based packet routing for sidelink relay in accordance with embodiments of the current invention.

(12) FIG. 11 is an exemplary flow chart for a relay UE in the L2-based sidelink relay communication path in accordance with embodiments of the current invention.

(13) FIG. 12 is an exemplary flow chart for an end-node UE in the L2-based sidelink relay communication path in accordance with embodiments of the current invention.

## DETAILED DESCRIPTION

(14) Reference will now be made in detail to some embodiments of the invention, examples of which are illustrated in the accompanying drawings.

(15) FIG. 1 is a schematic system diagram illustrating an exemplary wireless network for layer-2 (L2)-based sidelink relay in accordance with embodiments of the current invention. Wireless system **100** includes one or more fixed base infrastructure units forming a network distributed over a geographical region. The base unit may also be referred to as an access point, an access terminal, a base station, a Node-B, an eNode-B (eNB), a gNB, or by other terminology used in the art. The network can be homogeneous network or heterogeneous network, which can be deployed with the same frequency or different frequency. gNB **101**, gNB **102** and gNB **103** are base stations in the NR network, the serving area of which may or may not overlap with each other. Backhaul connections such as **131**, **132**, and **133**, connect the non-co-located receiving base units, such as gNB **101**, **102** and **103**. These backhaul connections can be either ideal or non-ideal. gNB **101** is connected with gNB **102** via Xnr interface **131** and is connected with gNB **103** via Xnr interface **132**. gNB **102** is connected with gNB **103** via Xnr interface **133**.

(16) Wireless network **100** also includes multiple communication devices or mobile stations, such user equipments (UEs) such as UEs **111**, **112**, **113**, **114**, **115** and **116**, **121**, **122**, **123**, **124**, **125**, **126**, and **127**. Communication devices or mobile stations in wireless network **100** may also refers to devices with wireless connectivity in a vehicle, such as mobile devices **118**, **117** and **128**. The exemplary mobile devices in wireless network **100** have sidelink capabilities. The mobile devices can establish one or more connections with one or more base stations, such as gNB **101**, **102**, and **103**. The mobile device may also be out of connection with the base stations with its access links but can transmit and receive data packets with another one or more other mobile stations or with one or more base stations through L2-based sidelink relay.

(17) In one novel aspect, L2-based sidelink relay for packet routing is configured. In a first embodiment, the L2-based UE-to-Network one-hop relay using sidelink is configured. A remote UE **111** and gNB **103** forms an end-to-end path **181** through a L2-based sidelink relay with a relay UE **121**. End-to-end path **181** includes an access link **151** between gNB **103** and relay UE **121** and a sidelink **161** between remote UE **111** and relay UE **121**. In a second embodiment, the L2-based UE-to-Network multi-hop relay using sidelink is configured. A remote UE **112** and gNB **102** forms an end-to-end path **182** through a L2-based sidelink relay with a relay UE **122** and another relay UE **123**. End-to-end path **182** includes an access link **152** between gNB **102** and relay UE **122**, sidelink **162** between relay UE **122** and relay UE **123**, and sidelink **163** between remote UE **112** and relay UE **123**. In a third embodiment, the L2-based UE-to-UE one-hop relay using sidelink is configured. An end node UE **113** and another end node UE **114** forms an end-to-end path **183** through a L2-based sidelink relay with a relay UE **125**. End-to-end path **183** includes a sidelink **164** between end node UE **113** and relay UE **125** and a sidelink **165** between end node UE **114** and relay UE **125**. In a fourth embodiment, the L2-based UE-to-UE multi-hop relay using sidelink is configured. An end node UE **115** and another end node UE **116** forms an end-to-end path **184** through a L2-based sidelink relay with a relay UE **126** and another relay UE **127**. End-to-end path **184** includes a sidelink **166** between end node UE **115** and relay UE **126**, a sidelink **167** between relay UE **126** and relay UE **127**, and a sidelink **168** between end node UE **116** and relay UE **127**. In another embodiment, a relay mobile device is configured with multiple remote mobile devices or multiple end node mobile devices. A relay UE **128**, with an access link **153** to gNB **101** is configured with two remote UEs **117** and **118** through sidelink **171** and **172**, respectively. In other embodiments, a relay mobile device can be configured for multiple UE-to-UE relay paths.

(18) FIG. 1 illustrates different links and their interfaces for L2-based sidelink relay. An access link **191** is a link between a base station, such as gNB and a mobile device, such as a UE. The UE can be a remote UE or a relay UE. The access link includes both the uplink (UL) and the downlink (DL) between the base station and the mobile device. The interface for the access link is an NR Uu

interface. In one embodiment, the remote UE also establishes access link with a base station. A sidelink **192** is a link between two mobile devices and uses PC5 interface. The sidelink can be a link between a remote UE/end-node UE and a relay UE or a link between two relay mobile devices/UEs for the multi-hop relay. The end-to-end link **193** for a relay path can be a link between two end-node mobile devices for a UE-to-UE relay or a base station to mobile device for a UE-to-Network relay. An Xn link **194** is the backhaul link between two base stations, such as gNBs using the Xn interface. In one embodiment, candidate relay UE information is transmitted to the base station via the Xn link.

(19) FIG. 2 illustrates an exemplary NR wireless system with centralized upper layers of the NR radio interface stacks in accordance with embodiments of the current invention. Different protocol split options between central unit and lower layers of gNB nodes may be possible. The functional split between the central unit and lower layers of gNB nodes may depend on the transport layer. Low performance transport between the Central Unit and lower layers of gNB nodes can enable the higher protocol layers of the NR radio stacks to be supported in the Central Unit, since the higher protocol layers have lower performance requirements on the transport layer in terms of bandwidth, delay, synchronization and jitter. In one embodiment, SDAP and PDCP layer are located in the central unit, while RLC, MAC and PHY layers are located in the distributed unit. A Core unit **201** is connected with one central unit **211** with gNB upper layer **252**. In one embodiment **250**, gNB upper layer **252** includes the PDCP layer and optionally the SDAP layer. Central unit **211** is connected with distributed units **221**, **222**, and **223**. Distributed units **221**, **222**, and **223** each corresponds to a cell **231**, **232**, and **233**, respectively. The distributed units, such as **221**, **222** and **223** includes gNB lower layers **251**. In one embodiment, gNB lower layers **251** include the PHY, MAC and the RLC layers. In another embodiment **260**, each gNB has the protocol stacks **261** including SDAP, PDCP, RLC, MAC and PHY layers.

(20) FIG. 3 illustrates simplified block diagrams of a base station and a mobile device/UE for L2-based sidelink relay in accordance with embodiments of the current invention. gNB **302** has an antenna **356**, which transmits and receives radio signals. An RF transceiver circuit **353**, coupled with the antenna, receives RF signals from antenna **356**, converts them to baseband signals, and sends them to processor **352**. RF transceiver **353** also converts received baseband signals from processor **352**, converts them to RF signals, and sends out to antenna **356**. Processor **352** processes the received baseband signals and invokes different functional modules to perform features in gNB **302**. Memory **351** stores program instructions and data **354** to control the operations of gNB **302**. gNB **302** also includes a set of control modules **355** that carry out functional tasks to communicate with mobile stations.

(21) UE **301** has an antenna **335**, which transmits and receives radio signals. An RF transceiver circuit **363**, coupled with the antenna, receives RF signals from antenna **335**, converts them to baseband signals, and sends them to processor **362**. In one embodiment, the RF transceiver may comprise two RF modules (not shown). A first RF module is used for HF transmitting and receiving, and the other RF module is used for different frequency bands transmitting and receiving which is different from the HF transceiver. RF transceiver **363** also converts received baseband signals from processor **362**, converts them to RF signals, and sends out to antenna **335**. Processor **362** processes the received baseband signals and invokes different functional modules to perform features in UE **301**. Memory **361** stores program instructions and data **364** to control the operations of UE **301**. Antenna **335** sends uplink transmission and receives downlink transmissions to/from antenna **356** of gNB **302**.

(22) Mobile station **301** also includes a set of control modules that carry out functional tasks. These control modules can be implemented by circuits, software, firmware, or a combination of them. An L2 sidelink relay circuit **391** obtains an L2 relay configuration. An L2 packet routing circuit **392** configures an L2 packet routing to a remote UE for L2-based packet relay using a first sidelink of the UE based on the L2 relay configuration, wherein an L2 relay path is established for the remote

UE using the first sidelink. An L2 packet relay circuit **393** performs packet data relay to and from the remote UE based on the configured L2 packet routing. A relay release circuit **394** releases the configured L2 packet routing upon detecting one or more releasing triggering events.

(23) FIG. 4 illustrates exemplary diagrams for a L2-based UE-to-Network relay using sidelink in accordance with embodiments of the current invention. In one embodiment, the UE-to-Network relay with sidelink is a one-hop relay **410**. A remote UE **412** established a relay path with a gNB **411** through a relay UE **413**. Relay UE **413** communicates with gNB **411** via access link **415**. Relay UE **413** communicates with remote UE **412** through sidelink **416**. gNB **411** transmits data packets destined to remote UE **412** through DL to relay UE **413** and receives data packets from remote UE **412** through UL from relay UE **413**. The relay path between remote UE **412** and gNB **411** includes access link **415** and sidelink **416**. In another embodiment, a multi-hop UE-to-Network relay **430** is configured. A remote UE **432** established a relay path with a gNB **431** through relay UEs **433** and **434**. Relay UE **433** communicates with gNB **431** via access link **435**. Relay UE **433** communicates with relay UE **434** through sidelink **436**. Relay UE **434** communicates with remote UE **432** through sidelink **437**. gNB **431** transmits data packets destined to remote UE **432** through DL to relay UE **433**, which is forwarded to relay UE **434** through sidelink **436**. gNB **431** receives data packets from remote UE **432** through UL from relay UE **433**, which is forwarded from relay UE **434** through sidelink **436**. The relay path between remote UE **432** and gNB **431** includes access link **435** and sidelinks **436** and **437**. Multi-hop UE-to-Network relay can be configured with two or more relay UEs. In one embodiment, the one or more relay UEs are connected with the network end-node, such as gNB **411** and **431**. In another embodiment, multiple relay UEs may be connected with different gNBs. For example, relay UE **433** is connected with network end-node gNB **431**, while relay UE **434** is connected with a different gNB. gNB **431** gets UE information of relay UE **434** from its serving gNB through backhaul connections, such as the Xnr interface. In one embodiment, the remote UE, such as remote UE **412** and remote UE **432**, is connected with the network end-node, such as gNB **411** and gNB **431**, respectively. In another embodiment, the remote UE is connected with a different gNB. In yet another embodiment, the remote UE has no direct network connection. In both the one-hop relay and the multi-hop relay, the packet routing occurs at the base station, the one or more relay UEs and the remote UE.

(24) FIG. 5 illustrates exemplary diagrams for a L2-based UE-to-UE relay using sidelink in accordance with embodiments of the current invention. In one embodiment, the UE-to-UE relay with sidelink is a one-hop relay **510**. An end-node UE **512** established a data path with another end-node UE **511** through a relay UE **513**. Relay UE **513** communicates with end-node UE **511** via sidelink **515**. Relay UE **513** communicates with end-node UE **512** through sidelink **516**. End-node UE **511** transmits data packets destined to end-node UE **512** through sidelink **515** to relay UE **513** and receives data packets from end-node UE **512** through sidelink **516** from relay UE **513**. The relay path between end-node UE **512** and end-node UE **511** includes two sidelinks **515** and **516**.

(25) In another embodiment, a multi-hop UE-to-UE relay **550** is configured. Two end-node UEs **551** and **552** is configured with multi-hop UE-to-UE relay communication through sidelinks. In one embodiment, multiple relay paths are configured for UE-to-UE relay between end-node UE **551** and end-node UE **552**. In one embodiment, multiple relay UE candidates are identified, including UE **553**, **554**, **555**, **556**, and **557**. Based on the measurement reports from the candidate UEs, one or more relay paths are configured for end-node UEs **551** and **552** for L2-based UE-to-UE relay. In an exemplary scenario, end-node UE **551** has sidelink **561** and **566** with relay UE **554** and **556**, respectively. Relay UE **554** has sidelinks **562** and **564** with relay UE **553** and **555**, respectively. Relay UE **556** has one sidelink **567** with relay UE **557**. Relay UEs **553**, **555**, and **557** have sidelinks **563**, **565** and **568** with end-node UE **552**, respectively. Three exemplary relay paths are configured for UE-to-UE L2-based sidelink relay between end-node UE **551** and **552**. Relay path-1 **571** includes sidelink **561** between end-node UE **551** and relay UE **554**, sidelink **562** between relay UE **554** and relay UE **553**, and sidelink **563** between relay UE **553** and end-node UE



552. Relay path-2 572 includes sidelink 561 between end-node UE 551 and relay UE 554, sidelink 564 between relay UE 554 and relay UE 555, and sidelink 565 between relay UE 555 and end-node UE 552. Relay path-3 573 includes sidelink 566 between end-node UE 551 and relay UE 556, sidelink 567 between relay UE 556 and relay UE 557, and sidelink 568 between relay UE 557 and end-node UE 552. One relay path is selected to perform data communications between the end-node UEs. In one embodiment, the multiple relay paths configuration may include both multi-hop relay configuration and one-hop relay configuration. The end-nodes can switch among different configured relay paths based on switching rules. An end-node in a relay configuration can be a network node, such as a gNB or a mobile station node, such as a UE. In other embodiments, the multiple relay paths configuration applies to different type of sidelink relays as described above, including the one-hop UE-to-Network relay, the multi-hop UE-to-network relay, the one-hop UE-to-UE relay, and the multi-hop UE-to-UE relay. Similar to UE-to-Network relay discussed above, multiple relay UEs are connected in the wireless network with one or more network nodes.

(26) In one novel aspect, the wireless relay using sidelink is implemented at L2 for packet routing. In one embodiment, an adaptation layer is introduced on top of the radio link control (RLC) layer for purpose of packet routing and other functionalities, such as bearer mapping, flow control, radio link failure (RLF) indication, and other functionalities. For a relay path, there are two end-nodes communicating with each other through one or more relay nodes. For the protocol stack illustrations below, the relay nodes are mobile devices with sidelink configured. The two end-nodes can be both mobile devices, such as end-node UEs. In other embodiments, one end-node is a network node, such as a gNB in the NR network, while the other end-node is a mobile device, such as a UE.

(27) FIG. 6 illustrates exemplary diagrams of the user plane protocol stacks for packet routing of L2-based sidelink relay in accordance with embodiments of the current invention. An exemplary relay path stacks 600 includes two end node stacks 601 and 604, and two relay nodes stacks 602 and 603. The lower layer wireless channel 660 is established through the PHY, MAC, RLC and ADAPT layers of each node on the relay path. A first wireless connection 661 is established between lower layer protocol stack of end-node 601 and a first lower layer protocol stack of relay node 602. A second wireless link 662 is established between the second lower layer protocol stack of relay node 602 and a first lower layer protocol stack of relay node 603. A second lower layer protocol stack of relay node 603 establishes a third wireless link 663 with lower layer protocol stack of end-node 604. In one embodiment, for a UE-to-Network relay, the first wireless link 661 is an RLC wireless link via an Uu interface between relay node 602 and a network end node 601. In another embodiment, for a UE-to-UE relay, the first wireless link 661 is a sidelink via the PC5 interface between the relay node 602 and a mobile station end-node 601. On the user plane, end-to-end protocol connection 650 are established directly between the protocol stacks at the IP layer, the SDAP layer and the PDCP layer of end-node 601 and 604. The ADAPT layer of each node is used for packet routing of the L2-based sidelink relay. In one embodiment, each relay node is configured with two ADAPT layer stack. Relay node 602 has ADAPT 621 and 622. Relay node 603 has ADAPT 631 and 632. Each ADAPT stack of the one or more relay nodes is connected with an end-node ADAPT stack. ADAPT 621 of relay node 602 is connected with ADAPT 611 of end-node 601. ADAPT 632 of relay node 603 is connected with ADAPT 641 of end-node 604. In another embodiment, there is no ADAPT configured for the last hop of the UE-to-Network relay path. For the last hop of relay, which is the sidelink between the relay node and the mobile station/UE end node, there is no ADAPT layer configured for this sidelink. ADAPT 632 of relay node 603 and ADAPT 641 of end node 604 are not configured for the relay path stack 600.

(28) FIG. 7 illustrates exemplary diagrams of the control plane protocol stacks for packet routing of L2-based sidelink relay in accordance with embodiments of the current invention. An exemplary relay path stacks 700 includes two end node stacks 701 and 704, and two relay nodes stacks 702 and 703. The lower layer wireless channel 760 is established through the PHY, MAC, RLC and

ADAPT layers of each node on the relay path. A first wireless connection **761** is established between lower layer protocol stack of end-node **701** and a first lower layer protocol stack of relay node **702**. A second wireless link **762** is established between the second lower layer protocol stack of relay node **702** and a first lower layer protocol stack of relay node **703**. A second lower layer protocol stack of relay node **703** establishes a third wireless link **763** with lower layer protocol stack of end-node **704**. In one embodiment, for a UE-to-Network relay, the first wireless link **761** is an RLC wireless link via an Uu interface between relay node **702** and a network end node **701**. In another embodiment, for a UE-to-UE relay, the first wireless link **761** is a sidelink via the PC5 interface between the relay node **702** and a mobile station end-node **701**. On the control plane, end-to-end protocol connection **750** are established directly between the protocol stacks at the NAS layer, the RRC layer and the PDCP layer of end-node **701** and **704**. The ADAPT layer of each node is used for packet routing of the L2-based sidelink relay. In one embodiment, each relay node is configured with two ADAPT layer stack. Relay node **702** has ADAPT **721** and **722**. Relay node **703** has ADAPT **731** and **732**. Each ADAPT stack of the one or more relay nodes is connected with an end-node ADAPT stack. ADAPT **721** of relay node **702** is connected with ADAPT **711** of end-node **701**. ADAPT **732** of relay node **703** is connected with ADAPT **741** of end-node **704**. In another embodiment, there is no ADAPT configured for the last hop of the UE-to-Network relay path. For the last hop of relay, which is the sidelink between the relay node and the mobile station/UE end node, there is no ADAPT layer configured for this sidelink. ADAPT **732** of relay node **703** and ADAPT **741** of end node **704** are not configured for the relay path stack **700**.

(29) FIG. **8** illustrates exemplary flow diagrams of establishing the L2-based packet routing for sidelink relay in accordance with embodiments of the current invention. In one novel aspect, the L2-based sidelink relay is configured by a network node, such as a base station. Sidelink communication path between the base station and the remote UE are established upon reception of the UE information message from one or more candidate relay UEs and the remote UE. Packet routing information are configured for the nodes within the L2-based sidelink relay path. Upon the relay communication path is established, the data packets are routed between the end nodes through the relay nodes. The packet routing information for the L2-based sidelink relay path is updated upon receiving UE information from one or more candidate relay UEs and the remote UE. The L2-based sidelink relay path is released upon detecting releasing triggering events. A gNB **801** is connected with a relay UE **802**, a relay UE **803** and a remote UE **804**. At step **811**, relay UE **802** establishes RRC connection with gNB **801**. At step **812**, relay UE **803** establishes RRC connection with gNB **801**. At step **813**, remote UE **804** establishes RRC connection with gNB **801**. In one embodiment, gNB **801** broadcasts an indication to express its support of UE-to-Network relay operation. In another embodiment, gNB **801** broadcasts the corresponding configuration parameters to support sidelink relay discovery and communication. In other embodiments, steps **811**, **812**, **813** may be performed in other sequences.

(30) At step **821**, remote UE **804** transmits a relay-interest indication, which indicate that the UE is interested in establishing an L2-based sidelink relay transmission (TX) and receiving (RX). Optionally, the UE measurement report from UE **804** is also sent to gNB **801**. In one embodiment, remote UE **804** sends the relay-interest indication to the network to indicate the interest to do radio communication, including TX, RX or the combination, via L2-based sidelink relay. The relay-interest indication from the UE may also include a particular frequency or a frequency list for the sidelink relay. Optionally together with the relay TX/RX interest to the gNB, remote UE **804** also reports the UE radio signal measurement result, e.g. reference signal received power (RSRP), reference signal received quality (RSRQ), or signal to interference plus noise ratio (SINR), towards one or more peer UEs over one or more sidelinks. The UE report from remote UE **804** may also include the radio signal measurement result, e.g. RSRP, RSRQ, or SINR, towards its camped cell. In one embodiment, the UE report from remote UE **804** is carried in the SidelinkUEInformationNR or SidelinkUEInformationNR PC5 message. The measurement can be based on the preconfigured

resources, the resources indicated in system information, or resources included in previously received dedicated signal message.

(31) In one embodiment, the relay-interest indication is decoupled from the UE measurement report. Upon receiving the relay-interest indication from a UE, based on the received relay-interest indication from the UE, the gNB configures the UE to do measurement via RRC Reconfiguration message with measurement configuration. The UE measurement report includes a sidelink measurement report including radio signal measurement result, e.g. RSRP, RSRQ, or SINR, on one or more peer UEs over the sidelink. The UE measurement report further includes the radio signal measurement result, e.g. RSRP, RSRQ, or SINR, towards its camped cell if any. In one embodiment, the sidelink measurement report is reported per peer UE. In another embodiment, a specific UE ID is used to identify a particular peer UE and the sidelink measurement report has a list of measurement result each identified by the UE ID. The measurement configuration from the network configures one or more measurement objects including frequency, measurement event, etc. The sidelink oriented measurement event can refer to Event A4, which indicates a neighbor cell becomes better than a threshold defined for NR air interface. In one embodiment, the measurement event can refer to a sidelink specific measurement event: a neighbor UE becomes better than a threshold. In yet another embodiment, when the remote UE is served by a different gNB other than gNB **801**, the remote UE report may be sent to a different gNB and then be forwarded via X2 or Xn interface to the destination gNB **801**.

(32) At step **822**, relay UE **802** transmits a relay-interest indication and optionally the UE measurement report to gNB **801**. At step **823**, relay UE **803** transmits a relay-interest indication and optionally UE measurement report to gNB **801**. In one embodiment, relay UE **802** and/or relay UE **803** send the relay-interest indication to the network to indicate the interest to do radio communication, including TX, RX or the combination, via L2-based sidelink relay. The relay-interest indication from the UE also includes a particular frequency or a frequency list for the sidelink relay. Optionally together with the relay TX/RX interest report to the gNB, relay UE **802** and/or **803** also reports the UE radio signal measurement result, e.g. reference signal received power (RSRP), reference signal received quality (RSRQ), or signal to interference plus noise ratio (SINR), towards one or more peer UEs over one or more sidelinks. The UE report from relay UE **802** and/or **803** may also include the radio signal measurement result, e.g. RSRP, RSRQ, or SINR, towards its camped cell. In one embodiment, the UE report from relay UE **802** and/or **803** is carried in the SidelinkUEInformationNR or SidelinkUEInformationNR PC5 message. The measurement can be based on the preconfigured resources, the resources indicated in system information, or resources included in previously received dedicated signal message. In one embodiment, the relay-interest indication from the relay UE is decoupled from the measurement result report. gNB **801**, via RRC Reconfiguration message with measurement configuration, configures the one or more relay UEs to do measurement based on the relay-interest indication from the relay UE. The one or more relay UEs report radio signal measurement result, e.g. RSRP, RSRQ, or SINR, on one or more peer UEs over corresponding sidelinks and the radio signal measurement result, e.g. RSRP, RSRQ, or SINR, towards corresponding camped cell. The measurement configuration behavior described above for remote UE applies to relay UEs. When a different base station/gNB serves the relay UE, the relay UE report may be sent to the corresponding serving base station/gNB and then be forwarded via X2 or Xn interface by that serving gNB to the destination gNB **801**. In other embodiments, steps **821**, **822**, **823** may be performed in other sequences.

(33) At step **831**, gNB **801** selects one or more relay UEs based on the information received from remote UE **804** and one or more candidate relay UEs. gNB **801** allocates an Adaptation (ADAPT) Layer Address for each node, including the remote UE and relay node UEs, and the base station/gNB **801**. In one embodiment, the ADAPT layer address is allocated per the specific UE ID received by gNB **801** in the measurement report. gNB **801** labels the paths for both downstream and upstream between gNB **801** and the remote UE **804** configured with different sets of one or

more relay UEs. A plural of relay paths may exist between the source node and the destination node depending on which one or more relay UEs are configured for the relay path. One relay path ID is assigned to identify one potential relay path. gNB **801** derives a particular routing table for each node of each corresponding relay path. In one embodiment, the ADAPT layer address of a UE, including a remote UE and a relay UE, is proposed by the corresponding UE via UE information report message to gNB **801**. In one embodiment, gNB **801** upon obtaining the ADAPT layer address for a UE adopts the proposed ADAPT layer address for packet routing purpose. In another embodiment, gNB **801** rejects the UE proposed ADAPT layer address. In other embodiments, gNB **801** adopts a selected group of ADAPT layer addresses proposed by corresponding one or more UEs while rejecting the rest of UE proposed ADAPT layer addresses. In one embodiment, the routing table for a UE includes the ADAPT layer address of the destination and the next hop. The relay path ID is optional in the routing table. The next hop ADAPT address identifies a downstream relay UE, or the remote UE for downstream within the relay path. The next hop ADAPT address identifies an upstream relay UE or the destination gNB for upstream within the relay path. When a plural of paths is configured for a pair of end nodes, multiple next hop ADAPT addresses can be put into the routing table. In one embodiment, a relay UE may hold multiple ADAPT layer addresses when it serves multiple remote UEs with one ADAPT layer address configured for each remote UE.

(34) gNB **801** sends relay path configuration with ADAPT addresses and routing tables to UEs **802**, **803** and **804** at steps **841**, **842**, and **843**, respectively. In other embodiments, steps **841**, **842**, **843** may be performed in other sequences. gNB **801** configures the ADAPT layer addresses and the calculated routing table for each UE node including both the remote UE and the one or more relay UEs. In one embodiment, the relay path is configured with direct configuration via air interface. The configured routing parameters is carried by Uu RRCReconfiguration message. In another embodiment, the relay path is configured with indirect configuration via PC5 interface. The configured routing parameters is carried by RRCReconfigurationSidelink message. In one scenario, one or more relay UEs or the remote UE is served by one or more other base stations. The configured routing parameters to the one or more relay UE and/or the remote UE out of gNB **801** coverage area are forwarded from their corresponding serving base station. When the UE, the relay UE or the remote UE, receives configured routing parameters, the UE updates the UE context to include the configured routing parameters. In one embodiment, a relay UE serves multiple remote UEs. The relay UE maintains multiple routing table with each identified by corresponding UE's ADAPT layer address and/or other unique UE IDs. At step **851**, packet transmitting and receiving is performed between gNB **801** and remote UE **804** via the L2-based sidelink relay path. For each data packet or control packet transmitted between gNB **801** and remote UE **804**, a routing header is put into the packet header by the source node for purpose of routing within the relay path. In one embodiment, the routing header includes the ADAPT layer address of the destination. The node receiving the packet, looks up the routing table and find the next hop address for the packet, and delivers the packet to the next hop accordingly. In one embodiment, there is no ADAPT between the last hop relay UE and the remote UE. The whole ADAPT layer header including the routing header is removed before the downstream packets is forwarded to the remote UE. For the upstream packets going to the first hop relay UE from the remote UE, a new ADAPT layer header including the routing header is added. In another embodiment, there is no intermediate relay UE. No ADAPT layer is deployed in between the relay path for the purpose of routing and packet routing functionality is disabled.

(35) FIG. **9** illustrates exemplary flow diagrams of updating the L2-based packet routing for sidelink relay in accordance with embodiments of the current invention. At step **910**, a packet routing via L2-based sidelink relay is established with a remote UE **904** by a gNB **901** through a relay UE **903**. At step **921**, the RRC connection between gNB **901** and relay UE **903** is released. The relay path between gNB **901** and remote UE **904** via relay UE **903** is no longer available. At

step **931**, gNB **901** configures another UE, relay UE **902** to perform radio signal measurement over sidelink. In one embodiment, the measurement configuration is forwarded to candidate UE **902** via Uu RRC message. In another embodiment, the measurement configuration is a forwarded RRC message over a PC5 interface, e.g. an RRC Reconfiguration with configured measurement object. In one embodiment, the measurement configuration sent to relay UE **902** is either triggered by the RRC connection release of the relay UE **903**, or is triggered in a dynamic or periodic manner for an update to the relay path. In yet another embodiment, gNB **901** commands one or more candidate UEs to perform measurement. At step **941**, candidate UE **902** sends gNB **901** the UE report based on the measurement configuration received from gNB **901**. The UE report includes camping cell measurement report and the sidelink measurement report from candidate UEs and the remote UE **904**. gNB **901** determines its update of the allocation of the ADAPT layer addresses and the routing table to each node within relay path to remote UE **904**. At step **951**, gNB **901** send configuration update with updated routing table to remote UE **904**. At step **952**, gNB **901** sends configuration update with updated routing table to relay UE **902**. In one embodiment, the configuration update is sent using RRC messages. Upon receiving the updated routing parameters, the remote UE **904** and relay UE **902** update the UE context to include the new configured routing parameters. In one embodiment, the new configured routing parameter includes ADAPT layer address and the updated routing table. The ADAPT layer address is optional in the updated configuration parameter. When there is a newly joining relay UE in the relay path, ADAPT layer address is mandatory. In one embodiment, more than one new relay UEs are added to the updated relay path. In another embodiment, more than one relay UEs update their routing parameters and/or more than one relay UEs are released from the relay path. At step **961**, new relay path is used for gNB **901** and remote UE **904** using relay UE **902**.

(36) FIG. **10** illustrates exemplary flow diagrams of the release procedure for the L2-based packet routing for sidelink relay in accordance with embodiments of the current invention. At step **1011**, L2-based packet routing with sidelink relay is established between gNB **1001** and remote UE **1004** through relay UE **1002** and relay UE **1003**. At step **1021**, the relay communication between gNB **1001** and remote UE **1004** is completed. gNB **1001**, via Uu RRC message or forwarded RRC message over PC5, sends RRC Reconfiguration message to relay UE **1002** and relay UE **1003** to release packet routing to remote UE **1004** at step **1031** and step **1032**, respectively. In one embodiment, the ADAPT layer address of the remote UE identifies the relay path to be released. When the relay UE receives the RRC message, the relay UE needs to remove the routing information specific to a particular remote UE within the UE context. When the relay UE serves multiple remote UE, the routing information specific to other remote UE(s) is kept in its UE context. At step **1033**, gNB **1001**, via Uu RRC message or forwarded RRC message over PC5, sends RRC Re-configuration message to release the packet routing configuration. Steps **1031**, **1032**, **1033** may be performed in other sequences. In one embodiment, the direct configuration via air interface is configured when the RRC message to release the routing information is carried by the Uu RRCReconfiguration message. In another embodiment, the indirect configuration via PC5 interface is configured when the RRC message to release the routing information is carried by RRCReconfigurationSideLink message. In yet another embodiment, the remote UE is out of coverage, the RRC message to release the routing information to the remote UE is forwarded by a relay UE. In one embodiment, when the relay UE is served by a different gNB, the RRC message to release routing information to the relay UE is forwarded by its serving gNB to the relay UE. At step **1061**, the L2-based sidelink relay path is released.

(37) FIG. **11** is an exemplary flow chart for a relay UE in the L2-based sidelink relay communication path in accordance with embodiments of the current invention. At step **1101**, the relay UE obtains an L2 relay configuration in a wireless network. At step **1102**, the relay UE configures an L2 packet routing to a remote UE for L2-based packet relay using a first sidelink of the relay UE based on the L2 relay configuration, wherein an L2 relay path is established for the

remote UE using the first sidelink. At step **1103**, the relay UE performs packet data relay to and from the remote UE based on the configured L2 packet routing. At step **1104**, the relay UE releases the configured L2 packet routing upon detecting one or more releasing triggering events.

(38) FIG. **12** is an exemplary flow chart for an end-node UE in the L2-based sidelink relay communication path in accordance with embodiments of the current invention. At step **1201**, the end-node UE obtains an L2 relay configuration in a wireless network. At step **1202**, the end-node UE configures an L2 packet routing for L2-based packet relay using a sidelink between the end-node UE and a first relay UE based on the L2 relay configuration, wherein an L2 relay path is established for the end-node UE using the sidelink. At step **1203**, the end-node UE performs packet data transmission and reception to and from an end-node based on the configured L2 packet routing. At step **1204**, the end-node UE releases the configured L2 packet routing upon detecting one or more releasing triggering events.

(39) Although the present invention has been described in connection with certain specific embodiments for instructional purposes, the present invention is not limited thereto. Accordingly, various modifications, adaptations, and combinations of various features of the described embodiments can be practiced without departing from the scope of the invention as set forth in the claims.

## Claims

1. A method comprising: receiving a layer-2 (L2) relay configuration message comprising an L2 configuration by a relay user equipment (UE) from a gNB in a wireless network, wherein the L2 relay configuration message includes at least one element of an adaptation layer address of a node in an L2 relay path, and wherein the adaptation layer is an L2 sublayer immediate above a radio link control (RLC) layer and immediate below a packet data convergence protocol (PDCP) layer for routing of L2-based sidelink relay, and wherein each adaptation layer address is allocated per a specific UE identification (ID); configuring, by the relay UE, an L2 packet routing to a remote UE for L2-based packet relay using a first sidelink of the relay UE based on the L2 relay configuration message and a routing table that includes one or more adaptation layer addresses, wherein each of the one or more adaptation layer addresses corresponds to one of one or more UEs in the L2 relay path, and wherein the L2 relay path is established for the remote UE using the first sidelink; performing packet data relay to and from the remote UE based on the configured L2 packet routing; and releasing the configured L2 packet routing upon detecting one or more releasing triggering events.
2. The method of claim 1, wherein the L2 relay configuration is generated by a first base station in the wireless network, and wherein the L2 relay configuration is based on UE information reports from a plurality of UE candidates for establishing the L2 relay path.
3. The method of claim 2, wherein a UE information report of each UE candidate includes one or more elements comprising an indication of interests for a sidelink relay, one or more frequencies available for a sidelink relay, and one or more UE measurement results over one or more corresponding sidelinks to one or more peer UEs.
4. The method of claim 2, wherein the first base station receives an UE information report of a candidate UE by an Uu interface RRC message from the candidate UE, or through an Xn interface from a second base station that receives the UE information report from the candidate UE through an RRC message.
5. The method of claim 2, wherein the relay UE obtains the L2 relay configuration from an Uu interface RRC message from the first base station, or from an Uu interface RRC message from a second base station that obtains the L2 relay configuration from the first base station through an Xn interface.
6. The method of claim 1, wherein the routing table includes one or more remote UEs with

corresponding one or more relay paths.

7. The method of claim 6, wherein the routing table includes one or more routing elements comprising one or more adaptation layer addresses, a relay path ID, and a next hop address.

8. The method of claim 1, wherein the relay path includes one or more relay hops.

9. The method of claim 1, further comprising: receiving an updated L2 relay configuration, wherein the updated L2 relay configuration is triggered by one or more updated UE information reports from one or more candidate UEs; and updating the L2 packet routing to the remote UE based on the updated L2 relay configuration.

10. A method comprising: receiving a layer-2 (L2) relay configuration message comprising an L2 configuration by a user equipment (UE) in a wireless network, wherein the L2 relay configuration message configures a node in an L2 relay path with an adaptation layer address and with a routing table that includes a destination node adaptation layer address and a next hop adaptation layer address, and wherein the adaptation layer is an L2 sublayer immediately above a radio link control (RLC) layer and immediately below a packet data convergence protocol (PDCP) layer for routing of L2-based sidelink relay packet routing, wherein each adaptation layer address corresponds to one UE in the L2 relay path, and wherein each adaptation layer address is allocated per a specific UE identification (ID); configuring an L2 packet routing for L2-based packet relay using a sidelink between the UE and a first relay UE based on the routing table and the adaptation layer addresses in the L2 relay configuration message, wherein the L2 relay path is established for the UE using the first sidelink; performing, by the UE, packet data transmission and reception to and from an end-node device based on the configured L2 packet; and releasing the configured L2 packet routing upon detecting one or more releasing triggering events.

11. The method of claim 10, wherein the end-node device is an end-node base station or an end-node UE.

12. The method of claim 10, wherein the L2 relay configuration is generated by a first base station in the wireless network, and wherein the L2 relay configuration is based on UE information reports from a plurality of UE candidates for establishing the L2 relay path.

13. The method of claim 12, wherein a UE information report of each UE candidate includes one or more elements comprising an indication of interests for a sidelink relay, one or more frequencies available for a sidelink relay, and one or more UE measurement results over one or more corresponding sidelinks to one or more peer UEs.

14. The method of claim 12, wherein the first base station receives an UE information report of a candidate UE from an Uu interface RRC message from the candidate UE, or through an Xn interface from a second base station that receives the UE information report from the candidate UE through an RRC message.

15. The method of claim 10, wherein the routing table includes one or more remote UEs with corresponding one or more relay paths.

16. The method of claim 10, wherein the relay path includes one or more relay hops.

17. The method of claim 10, further comprising: receiving an updated L2 relay configuration, wherein the updated L2 relay configuration is triggered by one or more updated UE information reports from one or more candidate UEs; and updating the L2 packet routing to the end-node device based on the updated L2 relay configuration.

18. A user equipment (UE), comprising: a transceiver that transmits and receives radio frequency (RF) signal in a wireless network; a layer-2 (L2) sidelink relay circuit that receives an L2 relay configuration message comprising an L2 configuration, wherein the L2 relay configuration message configures a node in an L2 relay path with an adaptation layer address and with a routing table that includes a destination node adaptation layer address and a next hop adaptation layer address, wherein an adaptation layer is an L2 sublayer immediately above a radio link control (RLC) layer and immediately below a packet data convergence protocol (PDCP) layer for routing of L2-based sidelink relay packet routing, wherein each adaptation layer address corresponds to

one UE in the L2 relay path and wherein each adaptation layer address is allocated per a specific UE identification (ID); an L2 packet routing circuit that configures an L2 packet routing to a remote UE for L2-based packet relay using a first sidelink of the UE based on the routing table and the adaptation layer address in the L2 relay configuration message, wherein the L2 relay path is established for the remote UE using the first sidelink; an I2 packet relay circuit that performs packet data relay to and from the remote UE based on the configured L2 packet routing; and a relay release circuit that releases the configured L2 packet routing upon detecting one or more releasing triggering events.

19. The UE of claim 18, wherein the L2 relay configuration is generated by a first base station in the wireless network, and wherein the L2 relay configuration is based on UE information reports from a plurality of UE candidates for establishing the L2 relay path.

20. The UE of claim 18, wherein the routing table includes one or more remote UEs with corresponding one or more relay paths.

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