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Methods and apparatus of sidelink relay based data communication

Abstract

Apparatus and methods are provided for sidelink relay-based UE-to-network communication. The disclosure describes the relay UE performing delayed relay forwarding upon determining the remote UE is in the DRX cycle based on the PC5 configuration. The relay UE buffers the relay traffic and/or sends a suspending indication to the base station to request the base station to suspend the relay traffic to the remote UE. The disclosure describes the relay UE monitoring paging occasions configured for itself and receives paging message from the network intended for the remote UE in one non-connected RRC state. The relay UE sends a PC5 paging message to the remote UE that is in the non-connected RRC state through the established SL based on the received paging message. The disclosure describes the network storing the SL association between the relay UE and the remote UE to the network.

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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/CN2021/095144, titled "Methods and Apparatus of Sidelink Relay Based Data Communication," with an international filing date of May 21, 2021. International Application PCT/CN2021/095144, in turn, claims priority under 35 U.S.C. § 120 and § 365(c) from PCT/CN2020/091597, titled "Methods and Apparatus of Sidelink Relay Based Data Communication," with an international filing date of May 21, 2020. This application is a continuation of International Application No. PCT/CN2021/095144. International Application No. PCT/CN2021/095144 is pending as of the filing date of this application, and the United States is an elected state in International Application No. PCT/CN2021/095144. 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 sidelink relay based data communication.
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. In 3GPP New Radio (NR), sidelink continues evolving. With new functionalities supported, the sidelink (SL) offers low latency, high reliability and high throughout for device-to-device communications. NR vehicle to everything (V2X) supports sidelink measurement. The V2X sidelink communication can be supported by unicast, groupcast, and broadcast. Using sidelink for wireless relay provides a reliable and efficient way for traffic forwarding. The sidelink relay evolves from the ProSe UE-to-Network relay at Layer-3 (L3) to UE-to-Network relay at layer-2 (L2), which is expected to forward the traffic between the remote UE and the base station at an adaptation layer between radio link control (RLC) layer and the packet data convergency protocol (PDCP) layer. For UE-to-Network relay operation, an important issue is to consider the relaying operation when the relay UE works at different RRC states. Different procedures are required to establish the connection between the remote UE and the base Station to enable relaying operation at the relay UE.
(3) Improvements and enhancements are required for sidelink relay operation considering different RRC state of the relay UE and the remote UE.

SUMMARY

(4) Apparatus and methods are provided for sidelink relay-based UE-to-network communication when the remote UE enters non-connected or DRX state. In one novel aspect, the relay UE performs delayed relay forwarding upon determining the remote UE is in the DRX cycle based on the PC5 configuration. In one embodiment, the delayed relay forwarding is buffering the relay traffic at the relay UE. In another embodiment, the delayed relay forwarding is sending a suspending indication to the base station to request the base station to suspend the relay traffic to the remote UE. The relay traffic is data traffic or a signaling message from the base station to the remote UE.

(5) In another novel aspect, the relay UE monitors paging occasions configured for itself and receives paging message from the network intended for the remote UE in one non-connected RRC state. The relay UE sends a PC5 paging message to the remote UE that is in the non-connected RRC state through the established SL based on the received paging message. In one embodiment, the relay UE reports the SL association between the relay UE and the remote UE upon transitioning from an RRC_CONNECTED state to one non-connected RRC state. In another embodiment, paging message includes one or more elements comprising an ID of the relay UE, an ID of the remote UE, and an SL association between the relay UE and the remote UE. In another embodiment, an RRC Reconfiguration message with the remote UE ID and/or the remote UE-relay UE SL association is received from the gNB. In yet another embodiment, the paging message received by the relay UE indicates a paging to the remote UE or a wake-up indication to the remote UE and is forwarded to the remote UE through the sidelink. The remote UE initiates a RRC Resume Request or RRC Setup Request upon receiving the paging indication or the wake-up indication.

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

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 sidelink relay-based data communication 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 an exemplary top-level functional diagram for the sidelink relay-based communication in accordance with embodiments of the current invention.

(5) FIG. **4** illustrates an exemplary signaling procedure for downlink data transmission through relay UE between remote UE in the long DRX state and base station in accordance with embodiments of the current invention.

(6) FIG. **5** illustrates exemplary diagrams of the relay UE forwarding paging messages from the network to the remote UE that is in one non-connected RRC state to wake up the remote UE in accordance with embodiments of the current invention.

(7) FIG. **6**A illustrates an exemplary flow diagram of the relay UE forwarding paging messages from the network to the remote UE that is in RRC_INACTIVE state to wake up the remote UE in accordance with embodiments of the current invention.

(8) FIG. **6**B illustrates an exemplary flow diagram of the relay UE forwarding paging messages from the network to the remote UE that is in RRC_IDLE state to wake up the remote UE in accordance with embodiments of the current invention.

(9) FIG. **7** illustrates an exemplary flow chart for the downlink data transmission through relay UE

between remote UE in the long DRX state and base station in accordance with embodiments of the current invention.
(10) FIG. **8** illustrates and exemplary flow chart the relay UE forwarding paging messages from the network to the remote UE that is in one non-connected RRC state in accordance with embodiments of the current invention.
DETAILED DESCRIPTION
(11) Reference will now be made in detail to some embodiments of the invention, examples of which are illustrated in the accompanying drawings.
(12) FIG. **1** is a schematic system diagram illustrating an exemplary wireless network for sidelink relay-based data communication 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 a homogeneous network or heterogeneous network, which can be deployed with the same frequency or different frequency. gNB **101** is an exemplary base station in the NR network.
(13) Wireless network **100** also includes multiple communication devices or mobile stations, such as user equipments (UEs) **111**, **112**, **113**, **114**, **115**, **116**, and **117**. 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**. UE **111** has an access link, with uplink (UL) and downlink (DL), with gNB **101**. UE **112**, which is also served by gNB **101**, may also establish UL and DL with gNB **101**. UE **111** also establishes a sidelink with UE **112**. Both UE **111** and UE **112** are in-coverage devices. Mobile devices on vehicles, such as mobile devices **113**, **114**, and **115**, also have sidelink capabilities. Mobile device **113** and mobile device **114** are covered by gNB **101**. Mobile device **113**, an in-coverage device, establishes sidelink with mobile device **114**, which is also an in-coverage device. Mobile device **115** on a vehicle, however, is an out-of-coverage device. In-coverage mobile device **114** establishes a sidelink with the out-of-coverage device **115**. In other embodiments, the mobile devices, such as UE **116** and **117**, may both be out-of-coverage but can transmit and receive data packets with another one or more other mobile stations with sidelink connections.
(14) FIG. **1** further illustrates simplified block diagrams of a base station and a mobile device/UE for the sidelink slot configuration and resource allocation. gNB **101** has an antenna **156**, which transmits and receives radio signals. An RF transceiver circuit **153**, coupled with the antenna, receives RF signals from antenna **156**, converts them to baseband signals, and sends them to processor **152**. RF transceiver **153** also converts received baseband signals from processor **152**, converts them to RF signals, and sends out to antenna **156**. Processor **152** processes the received baseband signals and invokes different functional modules to perform features in gNB **101**. Memory **151** stores program instructions and data **154** to control the operations of gNB **101**. gNB **101** also includes a set of control modules **155** that carry out functional tasks to communicate with mobile stations.
(15) UE **111** has an antenna **165**, which transmits and receives radio signals. An RF transceiver circuit **163**, coupled with the antenna, receives RF signals from antenna **165**, converts them to baseband signals, and sends them to processor **162**. 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 **163** also converts received baseband signals from processor **162**, converts them to RF signals, and sends out to antenna **165**. Processor **162** processes the received baseband signals and invokes different functional modules to perform features in the UE **111**. Memory **161** stores program instructions and data **164** to control the operations of the UE **111**. Antenna **165** sends uplink transmission and receives downlink

transmissions to/from antenna **156** of gNB **101**.
(16) The UE 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. A sidelink (SL) relay configuration module **191** configures a relay path between a remote UE and a base station, wherein the UE is connected with the base station through a Uu link in the wireless network. A sidelink controller **192** establishes an SL with the remote UE, wherein the SL is part of the relay path, and wherein a discontinuous reception (DRX) cycle is configured for the remote UE over the SL. A relay traffic receiver **193** receives relay traffic from the base station destined to the remote UE. A relay controller **194** performs delayed relay forwarding upon determining the remote UE is in the DRX cycle configured over the SL. A paging module **195** receives, from the wireless network, a paging message for the remote UE on a paging occasion (PO) configured for the relay UE, wherein the remote UE is in a non-connected RRC state comprising an RRC_IDLE state and an RRC_INACTIVE state, and wherein the paging message is based on an SL association between the UE and the remote UE and sends a PC5 paging message to the remote UE that is in the non-connected RRC state through the established SL based on the received paging message.
(17) 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 (CU) and distributed unit (DU) of gNB nodes may be possible. The functional split between the CU and DU of gNB nodes may depend on the transport layer. Low performance transport between the CU and DU of gNB nodes can enable the higher protocol layers of the NR radio stacks to be supported in the CU, 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 CU, while RLC, MAC and PHY layers are located in the DU. 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 **221**. Distributed units **221**, **222**, and **223** each correspond to a cell **231**, **232**, and **233**, respectively. The DUs, such as **221**, **222** and **223** include 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.
(18) FIG. **3** illustrates an exemplary top-level functional diagram for the sidelink relay-based communication in accordance with embodiments of the current invention. Relay UE **301** and remote UE **302** are connected with gNB **303** in the NR network through Uu links **311** and **312**, respectively. In one embodiment, a sidelink **313** is configured between relay UE **301** and remote UE **302**. Remote UE **302** should be reachable by network while the UE-to-Network relay is reachable by the network and the remote UE is reachable by the UE-to-Network relay. In general, the remote UE is only reachable via the relay UE if a unicast PC5 link, such as sidelink **313**, is established between the remote UE and the relay UE.
(19) In one novel aspect, illustrated in procedure **320**, the relay UE performs delayed relay forwarding upon determining the remote UE entering the discontinuous reception (DRX) mode over the sidelink **313**. As an exemplary relay path is established with Uu link **311** and relay link **313**, relay UE forwards relay traffic between gNB **303** and remote UE **302**. The relay traffic includes data traffic and signaling messages. The PC5 status of the remote UE **302** is not visible to gNB **303**. For example, with regard to PC5 link, sidelink **313**, when there is no traffic ongoing, the PC5 link is kept without traffic, which is identical to inactive status. In some scenarios, the Uu RRC state between remote UE **302** and gNB **303** is maintained without the consideration of the status of the PC5 link between remote UE **302** and relay UE **301**. Specific to the remote UE **302** in RRC connected state from Uu RRC perspective, enters into long DRX mode **361** from perspective of PC5. There may be desynchronization between Uu and PC5 for remote UE **302** when relay UE **301** itself is in RRC connected state and the network wants to communicate with the associated

remote UEs. At step **321**, gNB **303** sends relay traffic destined to remote UE **302** to relay UE **301**. Relay UE **301** determines that remote UE **302** is in DRX cycle configured over the SL. In one novel aspect, relay UE **301** performs delayed relay forwarding upon determining the remote UE is in the DRX cycle configured over the SL. In one embodiment, at step **322**, relay UE **301** buffers the relay traffic. In another embodiment **323**, relay UE **301** sends a suspending indication to the base station **303** to request the base station to suspend the relay traffic to the remote UE **302**. Relay UE **301** performs delayed relay forwarding by performs either step **322**, or **323**, or both **322** and **323**.

(20) In another novel aspect, as illustrated in exemplary procedure **330**, relay UE **301** forward paging messages from the network to the remote UE **302**, which is in one non-connected RRC state **362** and wakes up the remote UE. The non-connected RRC states including RRC_IDLE state and RRC_INACTIVE state. At step **331**, gNB **303** prepares to transmit relay traffic to remote UE **302**. At step **332**, gNB **303** sends relay UE **301** a paging message for remote UE **302** in a non-connected RRC state. The paging message is based on an SL association between the relay UE and the remote UE. Relay UE **301**, at step **321**, forward the paging message through PC5 sidelink **313** to the remote UE **302**. Remote UE **302** moves to RRC_CONNECTED state **363** based on the PC5 paging message.

(21) FIG. **4** illustrates an exemplary signaling procedure for downlink data transmission through relay UE between remote UE in the long DRX state and base station in accordance with embodiments of the current invention. Relay UE **401** is in RRC-Connected state **413** with an active Uu link with the gNB/base station **403**. Remote UE **402** is, at step **412**, in RRC connected state with no active traffic over the sidelink. At step **411**, remote UE **402** enters long DRX mode over the sidelink to sleep according to configured long DRX cycle. The state of remote UE **402** is an inactive status during RRC connected state. The network keeps the UE context of remote UE. Base station/gNB **403** does not know the inactive status of remote UE **402**.

(22) At step **421**, gNB **403** initiates downlink data transmission to the remote UE **402** via relay UE **401**. Since remote UE **402** is in long DRX mode over the sidelink, relay UE **401** cannot deliver the data to the remote UE **402**. In one novel aspect **430**, relay UE **401** performs delayed relay forwarding upon determining the remote UE **402** is in the DRX cycle configured over the SL. In one embodiment, at step **431**, relay UE **401** stores the downlink data in the buffer. It is assumed that relay UE **401** knows when the remote UE **402** will wake up according to the configured long DRX cycle. In one embodiment, the configured long DRX cycle is MAC parameter, which is configured via PC5 RRC message during the establishment of the PC5 relaying link. The configured long DRX cycle can be provided by gNB. Alternatively, it is decided by the relay UE. In any case, relay UE **401** knows the DRX cycle of one or more remote UE it established sidelink with.

(23) In one embodiment, relay UE **401** sends periodical or event-based report of its buffer status, for example, for downlink relaying purpose, to the gNB **403**. The buffer status enables gNB **403**, and/or other network entities to determine whether to schedule the downlink data transmissions to relay UE **401** for the relay traffic to remote UE **402** to avoid the buffer overflow within the relay UE **401**. In one embodiment, at step **432**, relay UE **401** sends data suspension request to the network entity, such as gNB **403**, to suspend the data transmission to remote UE **402** in order to wait for remote UE **402** to wake up, which is subject to the DRX cycle entered. In one embodiment, the network reduces the relay traffic through relay UE **401** to remote UE **402**. In one embodiment, relay UE **401** determines if the relay traffic coming from the network is manageable. If the relay traffic is manageable, relay UE **401** buffers the traffic without sending the suspend request to the network.

(24) At step **482**, relay UE **401** determines that the remote UE **402** exiting the DRX cycle. At step **441**, relay UE **401** delivers the buffered data to the remote UE **402** via PC5. At step **442**, relay UE **401** requests the network to resume the downlink data transmission. At step **413**, remote UE **402**

comes back to normal RRC connected state again. In one embodiment, the relay UE **402** indicates the time for data suspension according to the configured DRX cycle of remote UE **402**. The downlink data transmission is automatically resumed by the network after the expiration of the timer set following the time indicated from relay UE **401**. Step **442** can be omitted. In yet another embodiment, relay UE **401** reports the DRX cycle of the remote UE **402** to the gNB **403**. gNB **403** sends the downlink data to the remote UE **402** via relay UE **401** in a designated time pattern to avoid the data buffer for relaying at the relay UE **401**.

(25) In one novel aspect, the relay UE receives paging message from the network destined to the remote UE that is in the non-connected state and forwards the paging message to the remote UE using the sidelink. When the remote UE is inactive to the network, i.e., RRC_INACTIVE/RRC_IDLE from the perspective of indirect path with the network, its PC5 connection with UE-to-Network relay may be kept. Such PC5 connection may carry the forwarded paging message from UE-to-Network relay to remote UE. When the UE-to-Network relay is RRC_CONNECTED, the remote UE seen as RRC_INACTIVE/RRC_IDLE by the network would force the gNB to use paging to reach the remote UE. A likely scenario for sidelink relay operation is that the relay UE has multiple associations with a number of remote UEs. For example, the head node of car platooning (relay UE) serves one of his member cars, and some other member cars are communicating with the network with relaying supported by the head node. However, the other member cars have no traffic during this stage and may stays at RRC_INACTIVE/RRC_IDLE. During this period, the network can only reach these remote UEs by paging. The relay UE needs to monitor paging occasions for the remote UE while in RRC_CONNECTED. This puts a lot of burden for relay UE, since it in turn would require the UE-to-Network relay to monitor Paging Occasion(s) for multiple remote UEs, which would either cause undue complexity on the UE-to-Network Relay or otherwise impair the reachability of the Remote UE itself. In one embodiment, the network sends the paging message destined to the remote UE to the relay UE using the PO of the relay UE.

(26) FIG. **5** illustrates exemplary diagrams of the relay UE forwarding paging messages from the network to the remote UE that is in one non-connected RRC state to wake up the remote UE in accordance with embodiments of the current invention. Relay UE **501** established Uu link with gNB **503**. At step **561**, relay UE **501** establishes one or more SLs with one or more remote UEs, including a sidelink with remote UE **502**. The SL with remote UE **502** is part of the relay path. At step **562**, remote UE **502** enters one non-connected RRC state. The non-connected RRC state includes the RRC_INACTIVE state and the RRC_IDLE state. When the UE-to-Network relay is RRC_CONNECTED, the remote UE seen as RRC_INACTIVE/RRC_IDLE by the network would force the gNB to use paging to reach the remote UE.

(27) At step **563**, one or more network entities, such as gNB **503**, stores the relay UE-remote UE SL association information. There is no PC5 RRC state on the PC5 link. Following this principle, the UE may present different states for Uu and PC5. For example, when the remote UE stays or goes to RRC_INACTIVE state or RRC_IDLE state from Uu interface perspective, the UE is still active at PC5 link as long as the PC5 link between remote UE and relay UE is kept. The network (gNB and/or core network) needs to store the remote UE-relay UE SL association when there is unicast PC5 link between these remote UE and relay UE. The network, based on the stored remote UE-relay UE SL association information, always pages the relay UE to find the associated one or more remote UEs. The relay UE only needs to monitor the paging occasions for itself and forwards the paging message to the associated remote UE.

(28) There are different ways for the network/gNB to obtain the relay UE-remote UE SL association information. In one embodiment, the network is informed by relay UE **401** on the PC5 SL association between the relay UE and remote UE during the RRC connected stage or when the relay UE decides to leave the connected state. In one embodiment, the relay UE reports a list of remote UE that keeps PC5 link with relay UE to gNB during state transition (e.g., when going to

RRC_INACTIVE state). In another embodiment, the relay UE dynamically updates the list of remote UE(s) that keeps PC5 link with relay UE to gNB in RRC_CONNECTED state.
(29) In another embodiment, each remote UE associated with the relay UE informs the network (e.g., 5GC, 5G Core Network) during the RRC connected stage or when the remote UE decides to leave the connected state.
(30) In yet another embodiment, each remote UE follows the RRC state of the relay UE, i.e., if the relay UE stays at RRC_CONNECTED, all the associated remote UEs follows the same Uu RRC state. When the relay UE goes to RRC_INACTIVE/RRC_IDLE, all remote UEs transfer to the same RRC state as the relay UE. The relay UE cannot go to non-connected states, including RRC_INACTIVE/RRC_IDLE, if any remote UE has active traffic flows, which requires the relay UE to stay in RRC_CONNECTED. In one embodiment, to reduce the power consumption for non-active remote UE, a large long DRX cycle is configured. Remote UE is assumed to remain in RRC_CONNECTED state with long DRX cycle, while the UE-to-Network Relay UE itself is RRC_CONNECTED.
(31) Once the network obtains the remote UE-relay UE SL association, the network can page the non-connected remote UE by sending paging messages to the associated relay UE. At step **511**, the network, such as gNB **503**, prepares to send traffic to remote UE **502** based on the stored information of the remote UE-relay UE SL association.
(32) At step **521**, gNB **503** sends a paging message to relay UE **501** through the Uu link between relay UE **501** and gNB **503**. In one embodiment, relay UE **501** is also in the non-connected RRC state. Paging message from gNB **503** initiates a RACH procedure **522** from relay UE **501** first. In one embodiment, the paging message from gNB **503** pages both relay UE **501** and remote UE **502**. The paging message includes one or more elements comprising an identification (ID) of the relay UE, an ID of the remote UE, and an SL association between the relay UE and the remote UE. In one embodiment, the paging message is sent at the PO configured for relay UE **501**.
(33) In yet another embodiment, the paging message includes a paging indication or wake up indication to remote UE **502**. Relay UE **501**, upon receives the paging message, forward the paging indication or wake up indication to remote UE **502** through the PC5 sidelink. Remote UE **502**, upon receiving the paging indication or the wake-up indication, initiates a RRC Resume Request or RRC Setup Request to the network, using the PC5 RRC message through relay UE **501**. Relay UE **501** forwards the RRC Resume Request or RRC Setup Request to the network/gNB **503**. The network proceeds with RRC procedures such that remote UE **502** transfers back to RRC_CONNECTED state **541**.
(34) In one embodiment, at step **523**, the gNB **503** sends RRC Reconfiguration message to relay UE **502** following the paging message. In one embodiment, the RRC Reconfiguration message includes the remote UE ID and/or the remote UE-relay UE SL association. At step **531**, relay UE **501** forward the PC5 paging message to remote UE **502** through the sidelink. At step **532**, remote UE **502** sends PC5 RRC response message to relay UE **501**. At step **533**, relay UE **501** forwards the RRC response message from remote UE **501** to gNB **503**. At step **541**, remote UE **502** enters RRC_CONNECTED state. At step **551**, gNB **503** sends relay traffic for remote UE **502** to relay UE **501**. At step **552**, relay UE **501** forwards the relay traffic to remote UE **502**.
(35) FIG. **6**A illustrates an exemplary flow diagram of the relay UE forwarding paging messages from the network to the remote UE that is in RRC_INACTIVE state to wake up the remote UE in accordance with embodiments of the current invention. Relay UE **601**, in non-connected RRC state **612**, establishes a sidelink (SL) with remote UE **602**, which is in RRC_INACTIVE mode **611**. Relay UE **601** is connected with a gNB/base station **603** through a Uu link in the wireless network. Remote UE **602** and relay UE **601** keeps the PC5 sidelink at **613**. At step **621**, gNB **603** initiates the paging message to the relay UE **601** with the intention to wake up both relay UE **601** and remote UE **602** for downlink data transmission to the remote UE **602**. If relay UE **601** is in RRC_INACTIVE state, gNB **603** sends paging message to wake up both remote UE **602** and relay

UE **601**. If relay UE **601** is in RRC_IDLE state, gNB **603** sends paging message to wake up both remote UE **602** and relay UE **601**. In one embodiment, the remote UE index or identity is included in the paging message to allow relay UE **601** to identify which remote UE is the termination point for the downlink data transmission. In another embodiment, gNB **603** sends the remote UE index or identity in a dedicated RRC message to identify which remote UE is the termination point for the downlink data transmission.

(36) At step **622**, relay UE **601** performs RACH procedure towards gNB **603** as a response to the paging message from gNB **603**. At step **623**, message-5 is sent from relay UE **601** to gNB **603** to establish a RRC connection with the gNB **603**. At step **613**, relay UE **601** enters RRC_CONNECTED state. In one embodiment, at step **624**, gNB **603** sends a RRC Reconfiguration message to the remote UE with RRCResume. At step **631**, relay UE **601** forwards a PC5 paging message to remote UE **602** based on paging message at step **621** and optionally RRCReconfiguration message at step **624**. In one embodiment, PC5 paging message includes RRCResume. At step **632**, remote UE **602** responds PC5 RRC with an encapsulated Uu RRCResumeComplete message towards gNB **603**. At step **633**, the relay UE **601** forwards the encapsulated Uu RRCResumeComplete message towards gNB **603** over Uu. At step **614**, remote UE **602** goes to RRC_CONNECTED state with traffic.

(37) In one embodiment, relay UE **601** and remote UE **602** performs a handshake upon receiving the paging message at step **621**. Upon successful handshake indicating that the remote UE is responsive, remote UE **602** initiates a RRC Resume Request message through the sidelink to relay UE **601**. Relay UE **601** forwards the RRC Resume Request message through the Uu interface to gNB **603**. In another embodiment, if the relay UE goes to RRC_INACTIVE, and the associated remote UE goes also to RRC_INACTIVE, gNB uses RAN based paging to wake up relay UE before paging the remote UE for downlink data transmission. gNB knows the SL association between the relay UE and remote UE when they are both in RRC_INACTIVE. The SL association between the relay UE and remote UE when they are both in RRC_INACTIVE is stored by gNB. This SL association can be added into the UE context stored in gNB for UE in RRC_INACTIVE.

(38) FIG. **6**B illustrates an exemplary flow diagram of the relay UE forwarding paging messages from the network to the remote UE that is in RRC_IDLE state to wake up the remote UE in accordance with embodiments of the current invention. Relay UE **651**, in non-connected RRC state **662**, establishes a sidelink (SL) with remote UE **652**, which is in RRC_IDLE mode **661**. Relay UE **651** is connected with a gNB/base station **653** through a Uu link in the wireless network. Remote UE **652** and relay UE **651** keeps the PC5 sidelink at **663**. At step **671**, gNB **653** initiates the paging message to the relay UE **651** with the intention to wake up both relay UE **651** and remote UE **652** for downlink data transmission to the remote UE **652**. If relay UE **651** is in RRC_IDLE state, gNB **653** sends RAN paging message to wake up both remote UE **652** and relay UE **651**. If relay UE **651** is in RRC_IDLE state, gNB **653** sends paging message to wake up both remote UE **652** and relay UE **651**. In one embodiment, the remote UE index or identity is included in the paging message to allow relay UE **651** to identify which remote UE is the termination point for the downlink data transmission. In another embodiment, gNB **653** sends the remote UE index or identity in a dedicated RRC message to identify which remote UE is the termination point for the downlink data transmission.

(39) At step **672**, relay UE **601** performs RACH procedure towards gNB **653** as a response to the paging message from gNB **653**. At step **673**, message-5 is sent from relay UE **651** to gNB **653** to establish a RRC connection with the gNB **653**. At step **663**, relay UE **651** enters RRC_CONNECTED state. In one embodiment, at step **674**, gNB **653** sends a RRC Reconfiguration message to the remote UE with RRCSetup. At step **681**, relay UE **651** forwards a PC5 paging message to remote UE **652** based on paging message at step **671** and optionally RRCReconfiguration message at step **674**. In one embodiment, PC5 paging message includes RRCSetup. At step **682**, remote UE **652** responds PC5 RRC with an encapsulated Uu

RRCSetupComplete message towards gNB **653**. At step **683**, the relay UE **651** forwards the encapsulated Uu RRCSetupComplete message towards gNB **653** over Uu. At step **664**, remote UE **652** goes to RRC_CONNECTED state with traffic.
(40) In one embodiment, relay UE **651** and remote UE **652** performs a handshake upon receiving the paging message at step **671**. Upon successful handshake indicating that the remote UE is responsive, remote UE **652** initiates a RRC Setup Request message through the sidelink to relay UE **651**. Relay UE **651** forwards the RRC Setup Request message through the Uu interface to gNB **653**. In another embodiment, if the relay UE goes to RRC_IDLE, and the associated remote UE goes also to RRC_IDLE, gNB uses paging to wake up Relay UE before paging the remote UE for downlink data transmission. gNB knows the SL association between the relay UE and remote UE when they are both in RRC_IDLE. The SL association between the relay UE and remote UE when they are both in RRC_IDLE is stored by gNB. This SL association can be added into the UE context stored in gNB for UE in RRC_IDLE.
(41) FIG. **7** illustrates an exemplary flow chart for the downlink data transmission through relay UE between remote UE in the long DRX state and base station in accordance with embodiments of the current invention. At step **701**, the relay UE configures a relay path between a remote UE and a base station in a wireless network, wherein the relay UE is connected with the base station through a Uu link in the wireless network. At step **702**, the relay UE establishes a sidelink (SL) with the remote UE, wherein the SL is part of the relay path, and wherein a discontinuous reception (DRX) cycle is configured for the remote UE over the SL. At step **703**, the relay UE receives relay traffic from the base station destined to the remote UE. At step **704**, the relay UE performs delayed relay forwarding upon determining the remote UE is in the DRX cycle configured over the SL.
(42) FIG. **8** illustrates and exemplary flow chart the relay UE forwarding paging messages from the network to the remote UE that is in one non-connected RRC state in accordance with embodiments of the current invention. At step **801**, the relay UE establishes a sidelink (SL) with a remote UE, and wherein the relay UE is connected with a base station through a Uu link in the wireless network. At step **802**, the relay UE receives, from the wireless network, a paging message for the remote UE on a paging occasion (PO) configured for the relay UE, wherein the remote UE is in a non-connected RRC state comprising an RRC_IDLE state and an RRC_INACTIVE state, and wherein the paging message is based on an SL association between the relay UE and the remote UE. At step **803**, the relay UE sends a PC5 paging message to the remote UE that is in the non-connected RRC state through the established SL based on the received paging message. At step **804**, the relay UE forwards relay traffic from the base station to the remote UE.
(43) 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: configuring, by a relay user equipment (UE), a relay path between a remote UE and a base station in a wireless network, wherein the relay UE is connected with the base station through a Uu link in the wireless network; establishing, by the relay UE, a sidelink (SL) with the remote UE, wherein the SL is part of the relay path, and wherein a discontinuous reception (DRX) cycle is configured for the remote UE over the SL; receiving, by the relay UE, relay traffic from the base station destined to the remote UE, wherein the relay UE and the remote UE are in a radio resource control (RRC) connected state; and performing, by the relay UE, delayed relay forwarding upon determining the remote UE is asleep in a mode of the DRX cycle in which the relay UE cannot deliver data to the remote UE, and wherein the DRX cycle is configured

over the SL.
2. The method of claim 1, wherein the delayed relay forwarding performed by the relay UE comprises buffering the relay traffic at the relay UE.
3. The method of claim 2, further comprising: forwarding the buffered relay traffic and resuming relay traffic forwarding upon determining the remote UE exiting the DRX cycle.
4. The method of claim 1, performing the delayed relay forwarding comprises sending a suspending indication to the base station to request the base station to suspend the relay traffic to the remote UE.
5. The method of claim 4, further sending, by the relay UE, a resuming indication to the base station to request the base station to resume relay traffic to the remote UE upon determining the remote UE exiting the DRX cycle.
6. The method of claim 1, wherein the relay traffic is data traffic or a signaling message from the base station to the remote UE.
7. A user equipment (UE), comprising: a transceiver that transmits and receives radio frequency (RF) signal in a wireless network; a memory, and a processor coupled to the memory, the processor configured to configure a relay path between a remote UE and a base station, wherein the UE is connected with the base station through a Uu link in the wireless network; establish an SL with the remote UE, wherein the SL is part of the relay path, and wherein a discontinuous reception (DRX) cycle is configured for the remote UE over the SL; receive relay traffic from the base station destined to the remote UE, wherein the relay UE and the remote UE are in a radio resource control (RRC) connected state; and perform delayed relay forwarding upon determining the remote UE is asleep in a mode of the DRX cycle in which the relay UE cannot deliver data to the remote UE, and wherein the DRX cycle is configured over the SL.
8. The UE of claim 7, wherein performing the delayed relay forwarding involves one or more procedures comprising buffering the relay traffic at the UE and sending a suspending indication to the base station to request the base station to suspend the relay traffic to the remote UE.
9. The UE of claim 7, wherein the relay traffic is data traffic or a signaling message from the base station to the remote UE.