

INDIRECT PATH FAILURE PROCEDURE DUE TO LTM OF THE RELAY UE IN MULTI-PATH

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to
5 network units, methods, apparatuses, and computer readable medium for indirect path failure
procedure due to a layer 1 or layer 2 triggered mobility (LTM) of a relay user equipment (UE)
in multi-path communication.

BACKGROUND

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

[0003] A scenario of UE-to-network (U2N) relay has been discussed in the third generation
partner project (3GPP). An indirect path is a type of U2N transmission path, where data is
25 forwarded via a U2N relay UE between a U2N remote UE and the network. In some
scenarios, the U2N remote UE may be configured with multiple paths (multi-path) at least
including a direct path and an indirect path. An LTM of the relay UE may be supported,
and the impact on the remote UE should be further studied.

SUMMARY

30 **[0004]** The present disclosure relates to a first UE, a second UE, methods, apparatuses, and

computer readable medium for indirect path failure procedure in multi-path scenario. According to the proposed solution, an indirect path failure procedure may be initiated based on an LTM of the second UE (relay UE).

[0005] In some implementations, there is provided a first UE. The first UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the first UE to: receive, from a second UE, a first message comprising a notification message or a release message, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE; and transmit, to the base station via the direct path, based on the first message, a second message comprising measurement results of the second UE and at least one candidate relay UE.

[0006] In some implementations, there is provided a second UE. The second UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the second UE to: determine that an LTM of the second UE occurs; and transmit, to a first UE, a first message comprising a notification message or a release message indicating the LTM of the second UE, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE.

[0007] In some implementations, there is provided a first UE. The first UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the first UE to: receive, from a base station, a configuration comprising a first timer for path switching towards a candidate relay UE or a second timer for indirect path addition or change, wherein the first UE is configured with a direct path between the first UE and the base station and an indirect path between the first UE and the base station via a second UE; in accordance with a determination that a condition is met, perform one of: stopping the second timer, or ignoring the first timer.

[0008] In some implementations, there is provided a method performed by the first UE. The method comprises: receiving, from a second UE, a first message comprising a notification message or a release message, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE; and transmitting, to the base station via the direct path, based on the first message, a second message comprising measurement results of the second

UE and at least one candidate relay UE.

[0009] In some implementations, there is provided a method performed by the second UE. The method comprises: determining that an LTM of the second UE occurs; and transmitting, to a first UE, a first message comprising a notification message or a release message
5 indicating the LTM of the second UE, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE.

[0010] In some implementations, there is provided a method performed by the first UE. The method comprises: receiving, from a base station, a configuration comprising a first
10 timer for path switching towards a candidate relay UE or a second timer for indirect path addition or change, wherein the first UE is configured with a direct path between the first UE and the base station and an indirect path between the first UE and the base station via a second UE; in accordance with a determination that a condition is met, performing one of: stopping the second timer, or ignoring the first timer.

[0011] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a second UE, a first message comprising
15 a notification message or a release message, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE; and transmit, to the base station via the direct path, based on the first message, a second message comprising measurement results of the second UE
20 and at least one candidate relay UE.

[0012] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and
25 configured to cause the processor to: determine that an LTM of the second UE occurs; and transmit, to a first UE, a first message comprising a notification message or a release message indicating the LTM of the second UE, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE.

[0013] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and
30 configured to cause the processor to: receive, from a base station, a configuration comprising

a first timer for path switching towards a candidate relay UE or a second timer for indirect path addition or change, wherein the first UE is configured with a direct path between the first UE and the base station and an indirect path between the first UE and the base station via a second UE; in accordance with a determination that a condition is met, perform one of:
5 stopping the second timer, or ignoring the first timer.

[0014] In some implementations of the methods, the first UE, and the second UE described herein, the notification message comprises an indication type, and the indication type indicates an LTM of the second UE or a handover of the second UE.

[0015] In some implementations of the methods, the first UE, and the second UE described
10 herein, the release message comprises a proximity communication 5 (PC5) unicast link release message with a failure type, and the failure type indicates the LTM of the second UE or a handover of the second UE.

[0016] In some implementations of the methods, the first UE, and the second UE described herein, the second message comprises a sidelink UE information (SUI) message, and the SUI
15 message comprises measurement results of the first UE and the second UE.

[0017] In some implementations of the methods, the first UE, and the second UE described herein, the second message comprises an SUI message and the SUI message comprises a cause value indicating a PC5-S release or other failure.

[0018] In some implementations of the methods, the first UE, and the second UE described
20 herein, the second message comprises an indirect path failure information message with a failure type, wherein the failure type indicates the LTM of the second UE or a handover of the second UE.

[0019] In some implementations of the methods, the first UE, and the second UE described herein, the LTM of the second UE is determined upon an indication from a lower layer of the
25 second UE, and wherein the indication indicates that an LTM cell switch procedure is triggered.

[0020] In some implementations of the methods, the first UE, and the second UE described herein, the LTM of the second UE is determined upon a reception of an LTM cell switch command.

[0021] In some implementations of the methods, the first UE, and the second UE described
30 herein, the LTM of the second UE is determined upon performing an LTM cell switch

procedure following a cell selection procedure which is performed while a timer T311 is running.

5 [0022] In some implementations of the methods, the first UE, and the second UE described herein, the LTM of the second UE is determined based on an indication from an access stratum (AS) layer to an upper layer, and wherein the indication indicates an LTM of the second UE.

10 [0023] In some implementations of the methods and the first UE described herein, further comprising: starting the second timer upon a reception of a radio resource control (RRC) reconfiguration message for indirect path change, wherein RRC reconfiguration message does not include an indication of keeping the indirect path or does not include reconfiguration with synchronization.

15 [0024] In some implementations of the methods and the first UE described herein, the condition associated with stopping the second timer comprises one of: a detection of a radio link failure of a master cell group while the indirect path change is ongoing, or an initiation of a re-establishing procedure while the indirect path change is ongoing.

[0025] In some implementations of the methods and the first UE described herein, the configuration comprises a path switching configuration, and the condition associated with ignoring the first timer comprises an indication of keeping a current PC5 connection which is included in the configuration.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. 1 illustrates an example of a wireless communications system in which some embodiments of the present disclosure can be implemented;

[0027] FIG. 2A illustrates a schematic diagram of an example communication network in which some embodiments of the present disclosure can be implemented;

25 [0028] FIG. 2B illustrates an example RRC reconfiguration sidelink procedure;

[0029] FIG. 2C illustrates an example flow signalling for successful indirect path addition;

[0030] FIG. 2D illustrates a schematic diagram of an example communication network in which some embodiments of the present disclosure can be implemented;

30 [0031] FIG. 3 illustrates a signalling chart illustrating communication process in accordance with some example embodiments of the present disclosure;

[0032] FIG. 4 illustrates a signalling chart illustrating communication process for timer related operations in accordance with some example embodiments of the present disclosure;

[0033] FIG. 5 illustrates an example of a device that is suitable for implementing embodiments of the present disclosure;

5 [0034] FIG. 6 illustrates an example of a processor that is suitable for implementing some embodiments of the present disclosure;

[0035] FIG. 7 illustrates a flowchart of an example method implemented at a first UE in accordance with aspects of the present disclosure;

[0036] FIG. 8 illustrates a flowchart of an example method implemented at a second UE in
10 accordance with aspects of the present disclosure; and

[0037] FIG. 9 illustrates a flowchart of an example method implemented at a first UE in accordance with aspects of the present disclosure.

[0038] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

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DETAILED DESCRIPTION

[0039] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The
20 disclosure described herein can be implemented in various manners other than the ones described below. In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0040] References in the present disclosure to “one embodiment,” “an example
25 embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with
30 an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether

or not explicitly described.

[0041] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For
5 example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms. In some examples, values, procedures, or apparatuses are referred to as “best,” “lowest,” “highest,” “minimum,” “maximum,” or the like. It will be
10 appreciated that such descriptions are intended to indicate that a selection among many used functional alternatives can be made, and such selections need not be better, smaller, higher, or otherwise preferable to other selections.

[0042] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of embodiments. As used herein, the singular forms
15 “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “has,” “having,” “includes” and/or “including,” when used herein, specify the presence of stated features, elements, components and/or the like, but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof.
20 For example, the term “includes” and its variants are to be read as open terms that mean “includes, but is not limited to.” The term “based on” is to be read as “based at least in part on.” The term “one embodiment” and “an embodiment” are to be read as “at least one embodiment.” The term “another embodiment” is to be read as “at least one other embodiment.” The use of an expression such as “A and/or B” can mean either “only A” or
25 “only B” or “both A and B.” Other definitions, explicit and implicit, may be included below.

[0043] FIG. 1 illustrates an example of a wireless communications system 100 in which some embodiments of the present disclosure can be implemented. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network 106, and a packet data
30 network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a long term evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be

a 5G network, such as a new radio (NR) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless
5 communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0044] The one or more network entities 102 may be dispersed throughout a geographic
10 region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication
15 link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0045] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, message, broadcast,
20 etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some
25 implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols,
30 and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0046] The one or more UEs 104 may be dispersed throughout a geographic region of the

wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

10 [0047] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0048] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink (SL). For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

25 [0049] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an

access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

5 **[0050]** In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For
10 example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0051] An RU may also be referred to as a radio head, a smart radio head, a remote radio
15 head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as
20 virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0052] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional
25 split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaptation protocol (SDAP), Packet Data Convergence
30 Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU.

[0053] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0054] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-C, F1-U), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0055] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0056] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control

information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

5 **[0057]** In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource
10 structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network
15 entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0058] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and
20 a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic
25 prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0059] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for
30 example, a 10 millisecond (*ms*) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 *ms* duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a

frame may have the same duration.

[0060] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0061] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0062] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes

30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0063] In the context of the present disclosure, the term “proximity communication 5 (PC5) link” may be used interchangeably with PC5 interface, sidelink (SL), PC5 unicast link, SL unicast link, device-to-device (D2D) link, user-to-user link, UE-to-UE (U2U) link, or the like. The term “relay UE” may be used interchangeably with U2N relay UE, U2U relay UE, layer 2 (L2) relay UE, L2 U2N relay UE, L2 U2U relay UE, or the like. The term “relay UE ID” may be used interchangeably with link ID, path ID, L2 relay UE ID, or the like.

[0064] A wireless communications system may include one or more devices, such as one or more base stations and/or one or more UEs. In some implementations, two different UEs may communicate with each other via a PC5 link (PC5 interface), two different base stations may communicate with each other via an Xn link (Xn interface), and a UE and a base station may communicate with each via a Uu link (Uu interface).

[0065] FIG. 2A illustrates a schematic diagram of an example communication network 210 in which some embodiments of the present disclosure can be implemented. As shown in FIG. 2A, a UE 211 may communicate with a base station via a relay UE. The base station may be a gNB 212 or an NG-eNB 213, and the relay UE may be a relay UE 214 or a relay UE 215. For example, the NG-eNB 213 may be an evolved long term evolution (eLTE) base station that supports an NG interface. In some embodiments, the sidelink transmission and reception over the PC5 link are supported when the UE 211 is inside Next Generation Radio Access Network (NG-RAN) coverage, irrespective of which RRC state the UE is in, and also supported and when the UE 211 is outside NG-RAN coverage.

[0066] FIG. 2B illustrates an example RRC reconfiguration sidelink procedure 220. As shown in FIG. 2B, a UE 221 may transmit a reconfiguration message for Sidelink e.g. *RRCReconfigurationSidelink* message to a UE 222, and the UE 222 may transmit a reconfiguration complete message e.g. *RRCReconfigurationCompleteSidelink* message back to the UE 221.

[0067] The purpose of the procedure 220 is to modify a PC5-RRC connection, e.g. to establish/modify/release sidelink data radio bearers (DRBs), to configure NR sidelink

measurement and reporting, to configure sidelink channel state indicator (CSI) reference signal resources.

[0068] The UE (such as the UE 221) may initiate the sidelink RRC reconfiguration procedure and perform an operation on the corresponding PC5-RRC connection in following cases:

- the release of sidelink DRBs associated with the peer UE (such as the UE 222),
- the establishment of sidelink DRBs associated with the peer UE,
- the modification for the parameters included in sidelink radio bearer-configuration (SLRB-Config) of sidelink DRBs associated with the peer UE,
- the configuration of the peer UE to perform NR sidelink measurement and report,
- the configuration of the sidelink CSI reference signal resources.

[0069] FIG. 2C illustrates an example flow signalling 230 for successful second indirect path addition. Specifically, a remote UE 231 may perform a measurement report to the serving gNB 233 at step 1. A second indirect path via a relay UE may be decided to be added by the serving gNB 233 at step 2. In addition, at step 3, an RRC reconfiguration for path addition may be transmitted from the serving gNB 233 to the remote UE 231. Accordingly, a PC5 connection between the remote UE 231 and the relay UE 232 may be established based on a PC5 connection establishment message at step 4, and an RRC reconfiguration message for remote UE 231 may be transmitted from the serving gNB 233 to the relay UE 232. As such, an indirect path is added after an RRC reconfiguration complete message at step 6, and data transmission or reception at step 7 may be performed.

[0070] In a multi-path scenario, a remote UE may be configured with multiple paths, e.g. including a direct path and an indirect path. 3GPP is discussing a possibility of a failure type of the indirect path, for example, an IE for a failure report of the indirect path may involve a failure type including e.g., timer for path switching expiry, sl-Failure, n3c-Failure, Uu RLF of relay UE-, Cell reselection of relay UE, Uu RRC Failure of relay UE, indirectPathAddChangeFailure. The Uu RRC Failure of relay UE could be failure of RRC establishment procedure or RRC resume procedure. The n3c-Failure is associated with a failure of an N3C indirect path using Non-3GPP connection between the remote UE and the relay UE in multi-path.

[0071] Embodiments of the present disclosure provide a solution of communication. In

the solution, a relay UE may transmit a first message to the remote UE to indicate an LTM of the relay UE, and accordingly the remote UE may transmit a second message to the BS and the second message may include measurement results of the relay UE and at least one candidate relay UE. As such, behaviors of the UEs may be defined in case the LTM is supported by the relay UE, for example, the indirect path failure procedure may be initiated due to the LTM of the relay UE. Therefore, a communication for the remote UE may be guaranteed. Principles and implementations of the present disclosure will be described in detail below with reference to the figures.

[0072] FIG. 2D illustrates a schematic diagram of an example communication network 240 in which some embodiments of the present disclosure can be implemented. As shown in FIG. 2D, the communication network 240 may include a first UE 241, a second UE 242, and a BS 243.

[0073] The BS 243 and the first UE 241 may communicate with each other via a direct path. For example, the direct path may be associated with a Uu link there between. For example, the BS 243 may be a serving network device of the first UE 241, such as a serving gNB. There may be an indirect path between the first UE 241 and the BS 243 via the second UE 242. For example, the BS 243 may communicate with the second UE 242 via a Uu link, and the second UE 242 may communicate with the first UE 241 via a PC5 link. In this case, the first UE 241 may be a remote UE, and the second UE 242 may be a relay UE. It is to be understood that the multi-path scenario may be based on a DC framework or a non-DC framework, the present disclosure does not limit this aspect.

[0074] In some cases, as shown in FIG. 2D, there may be a third UE 244, for example, the first UE 241 and the BS 243 may communicate with each other via the third UE 244.

[0075] It is to be understood that the number of devices in FIG. 2D is given for the purpose of illustration without suggesting any limitations to the present disclosure.

[0076] Reference is now made to FIG. 3, which illustrates a signalling chart illustrating communication process 300 in accordance with some example embodiments of the present disclosure. The process 300 may involve the first UE 241, the second UE 242, and the BS 243 as shown in FIG. 2D. It is to be understood that the process 300 may also be applied to another scenario different from that shown in FIG. 2D, the present disclosure does not limit this aspect.

[0077] The first UE 241 may be in (i.e., stays at) an RRC connected state, and the first UE

241 is configured with multi-path including at least one direct path and at least one indirect path. The first UE 241 may access the BS 243 (such as serving gNB) via a direct path and an indirect path (via the second UE 242). In some example embodiments, the first UE 241 may transmit measurement results to the BS 243. In some examples, the first UE 241 may report the measurement results associated with one or more candidate cells or candidate relay UEs, based on a configuration from the BS 243.

[0078] In the process 300, the second UE 242 transmits a first message to the first UE 241 at 320. The first message may be a notification message or a release message.

[0079] In some implementations, the second UE 242 may transmit the first message to the first UE 241 when one of the following events occur: (1) a Uu radio link failure (RLF) of the second UE 242, (2) a reconfiguration with sync of the second UE 242, that is, a handover of the second UE 242, (3) a cell reselection of the second UE 242, (4) a Uu RRC connection establishment or resume failure of the second UE 242, (5) upon an indication by a lower layer that an LTM cell switch procedure is triggered, (6) upon a reception of an LTM cell switch command, or (7) upon performing an LTM cell switch following cell selection performed while a timer e.g. T311 was running.

[0080] Optionally, the second UE 242 may determine an LTM at 310, and the first message may be transmitted based on the determination of the LTM. In some implementations, the second UE 242 may receive an LTM cell switch command from a serving BS, such as the BS 243. For example, a MAC entity at a MAC layer of the second UE 242 may receive the LTM cell switch command. In some implementations, an LTM cell switch procedure for the second UE 242 may be triggered or be performed based on the LTM cell switch command. In some examples, a MAC entity at a MAC layer of the second UE 242 may provide an indication to an upper layer (such as an RRC layer) of the second UE 242, and the indication may indicate that the LTM cell switch procedure is triggered.

[0081] In some implementations, the first message may be a notification message, e.g. a *NotificationMessageSidelink* message. In some example embodiments, the notification message may indicate an LTM of the second UE 242 (i.e. the relay UE).

[0082] The second UE 242 (i.e. the relay UE) may initiate the transmission of the notification message (e.g. *NotificationMessageSidelink*) due to an indication by the lower layer that an LTM cell switch procedure is triggered, upon a reception of an LTM cell switch command, or upon performing an LTM cell switch following cell selection performed while

a timer T311 was running.

[0083] In some examples, the lower layer may be a MAC layer. In some examples, an upper layer (such as an RRC layer) of the second UE 242 may obtain an indication from the lower layer (e.g. the MAC layer), and the upper layer of the second UE 242 may transmit the notification message if the indication indicates that an LTM cell switch procedure is triggered.

[0084] The notification message (e.g. *NotificationMessageSidelink*) may include an indication type, which may indicate the LTM of the second UE 242. In some examples, the second UE 242 (i.e. the relay UE) may determine to transmit the notification message due to any of the events (5)-(7) above, and the second UE 242 (i.e. the relay UE) may set an information element (IE) of “indication type” to be relayUE-LTM. It is to be understood that the detailed content in the indication type is not limited in the present disclosure, some other format is also applied.

[0085] In some implementations, the first message may be a release message, e.g. a PC5 unicast link release message.

[0086] An AS layer of the second UE 242 (i.e. relay UE) may deliver an indication to the upper layer, where the upper layer may be one of: a PC5-S layer, a PC5-RRC layer, or a V2X layer. In some examples, the indication provided by the AS layer may indicate one of: Uu RLF of the second UE 242 (i.e. relay UE), a handover of the second UE 242 (relay UE), a cell reselection of the second UE 242 (i.e. relay UE), a Uu RRC connection establishment or resume failure of the second UE 242 (i.e. relay UE), or an LTM of the second UE 242 (i.e. relay UE). In some examples, the indication provided by the AS layer may indicate that a PC5-RRC connection is released. In some examples, a PC5 link identifier may be further provided from the AS layer to the upper layer. For example, the PC5 link identifier is used to indicate the PC5 unicast link whose PC5-RRC connection is released.

[0087] In some examples, an upper layer of the second UE 242 (i.e. relay UE) may determine to transmit the PC5 unicast link release message, based on the indication provided by the AS layer. For example, the V2X layer of the second UE 242 (i.e. relay UE) may release the PC5 unicast link associated with the PC5-RRC connection (which is indicated by the indication from the AS layer).

[0088] In some examples, the PC5 unicast link release message may include a failure type. For example, a corresponding failure type may be included in the PC5 unicast link release message, e.g., Disconnect request, by the upper layer (e.g. a PC5-S layer) of the second UE

242 (i.e. relay UE). For another example, the failure type may be set as “others”, as such, no new value is needed to be defined, and the specification impact may be minimized. In some instances, the failure type in the release message may be implemented as a cause value or the like, the present disclosure does not limit for this aspect.

5 [0089] In the process 300, the first UE 241 transmits a second message to the BS 243 at 330. In some implementations, the second message may be transmitted in response to a reception of the first message from the second UE 242.

[0090] In some implementations, the second message may include measurement results of the second UE 242 and one or more candidate relay UEs. In other words, the second
10 message may include measurement results of serving relay UE (i.e. the second UE 242) and at least one candidate relay UEs.

[0091] In some implementations, the first message may be a PC5 unicast link release message, in this case, a PC5-S layer of the first UE 241 may receive the first message from the second UE 242. In some examples, the PC5-S layer of the first UE 241 may provide an
15 indication to an RRC layer of the first UE 241, upon receiving the first message (e.g. the PC5 unicast link release message). For example, the indication from the PC5-S layer to the RRC layer may indicate that the PC5 unicast link release message has been received. In some embodiments, the first UE 241 may determine to transmit the second message to the BS 243 upon obtaining the indication from the PC5-S layer.

20 [0092] In some implementations, the first message may be a notification message, in this case, an RRC layer of the first UE 241 may receive the first message from the second UE 242. In some embodiments, the first UE 241 may determine to transmit the second message to the BS 243 upon receiving the first message from the second UE 242.

[0093] In some implementations, the second message may be a message comprising failure
25 information, such as an *IndirectPathFailureInformation* message. In some examples, the first UE 241 (i.e. the remote UE) may determine to initiate an indirect path failure information procedure upon a reception of the first message which may be a notification message or a release message. In some examples, the first UE 241 (i.e. the remote UE) may be triggered to transmit the second message (e.g., the *IndirectPathFailureInformation* message) based on
30 the first message from the second UE 242 (i.e. relay UE).

[0094] In some embodiments, the second message (e.g., the *IndirectPathFailureInformation* message) may include a failure type. In some examples,

the failure type may indicate an LTM of the second UE 242. In some examples, the failure type may be associated with the second UE 242 (i.e. the relay UE), and the failure type may indicate an LTM execution of the relay UE. In some other examples, the failure type may be set as “other”, “otherFailure”, or the like. As such, there is no need to define a new failure type for the LTM, and the specification impact may be minimized.

[0095] In some examples, the second message may be a sidelink UE information (SUI) message. The SUI message may include measurement results of the first UE 241 (i.e. the remoter UE) and the second UE 242 (i.e. the relay UE). The SUI message may include a cause value, which may indicate a PC5-S release or other failure. For example, the cause value in the SUI message may be set as “PC5-S release” or “others”. It is to be understood that the cause value in the SUI message may be set as a different value, for example, the cause value may indicate an LTM of the second UE 242.

[0096] In some examples, the second message may be a measurement report which may include measurement results of the second UE 242 and one or more candidate relay UEs. For example, the measurement report may be triggered when the first UE 241 receives the first message (e.g. the PC5 unicast link release message) from the second UE 242.

[0097] Additionally or alternatively, the indirect path associated with the second UE 242 may be released or may be changed to another indirect path based on the second message. As shown at 340 in FIG. 3, a direct path communication may be performed between the first UE 241 and the BS 243, or an indirect path change procedure may be performed.

[0098] According to some embodiments with reference to FIG. 3, in case a first message (a notification or release message) is received from a relay UE, the remote UE may transmit a second message to the BS, and the second message may include measurement results. As such, the BS may be aware of the indirect path failure information and may further perform further operations by using the measurement results. For example, the BS may determine a target relay UE based on the measurement results, and an indirect path addition or change procedure can be further performed. In this case, a communication for the remote UE can be guaranteed and the communication efficiency can be improved.

[0099] Reference is further made to FIG. 4, which illustrates a signalling chart illustrating communication process 400 in accordance with some example embodiments of the present disclosure. The process 400 may involve the first UE 241, the second UE 242, and the BS 243 as shown in FIG. 2D. It is to be understood that the process 400 may also be applied

to another scenario different from that shown in FIG. 2D, the present disclosure does not limit this aspect. The first UE 241 may be in (i.e., stays at) an RRC connected state.

[00100] In some cases, the first UE 241 is configured with a single path, e.g. a direct path. The first UE 241 may access the BS 243 (such as serving gNB) via the direct path.

5 **[00101]** In some cases, the first UE 241 is configured with a single path, e.g. an indirect path. The first UE 241 may access the BS 243 (such as serving gNB) via the indirect path (via the second UE 242).

[00102] In some cases, the first UE 241 is configured with multi-path including at least one direct path and at least one indirect path. The first UE 241 may access the BS 243 (such as
10 serving gNB) via a direct path and an indirect path (via the second UE 242).

[00103] In some example embodiments, the first UE 241 may transmit measurement results to the BS 243. In some examples, the first UE 241 may report the measurement results associated with one or more candidate cells or candidate relay UEs, based on a measurement configuration from the BS 243.

15 **[00104]** In the process 400, the BS 243 transmits a configuration to the first UE 241 at 410. The configuration may be an RRC reconfiguration message. The configuration may include a timer, such as a first timer and/or a second timer. In addition, the first UE 241 performs timer related operations at 420 based on the configuration.

[00105] In some implementations of the process 400, the configuration may include a second
20 timer for indirect path addition or change. For example, the second timer may be represented as T421, however, it is to be understood that the second timer may be in a different form, and the present disclosure does not limit for this aspect.

[00106] In some example embodiments, the first UE 241 access the serving cell via a direct path (single path). The first UE 241 may start the second timer for indirect path addition
25 upon a reception of the RRC reconfiguration message for indirect path addition purpose, e.g. upon a reception of the RRC reconfiguration message including *sl-IndirectPathAddChange*. In some example embodiments, the first UE 241 may be configured with multi-path. The first UE 241 may start the second timer for indirect path change upon a reception of the RRC reconfiguration message including *sl-IndirectPathAddChange* for indirect path change
30 purpose. In this case, the first UE 241 may start the second timer for indirect path addition or change procedure upon a reception of the RRC reconfiguration message including *sl-IndirectPathAddChange*, that is, the indirect path addition or change procedure is initiated as

the second timer is started.

[00107] In some examples, while the indirect path addition or change procedure is ongoing, the first UE 241 may initiate a re-establishment procedure upon detecting a RLF of the MCG (i.e. the direct path). In some examples, the first UE 241 may detect whether the RLF of the MCG occurs during the indirect path addition or change procedure. In some examples, the indirect path addition or change procedure is ongoing may be regarded as a multi-path indirect path addition or change procedure is ongoing, which means the second timer (e.g. T421) for indirect path addition or indirect path change is running.

[00108] In some examples, the first UE 241 may stop the second timer (e.g. T421) upon the initiation of the re-establishment procedure. For example, upon the RLF of the MCG is detected or upon the re-establishment procedure is initiated, the first UE 241 may stop the second timer (e.g. T421) for indirect path addition or indirect path change, if the second timer is running.

[00109] As such, there is no need to keep running the second timer is the re-establishment procedure is initiated, therefore, a processing at the remote UE can be simplified.

[00110] In some implementations of the process 400, the configuration may include a first timer for path switching towards a candidate relay UE. For example, the first timer may be represented as T420, however, it is to be understood that the first timer may be in a different form, and the present disclosure does not limit for this aspect.

[00111] In some example embodiments, the first UE 241 may be configured with multi-path, and the first UE 241 may transmit a measurement report which includes measurement results of one or more candidate relay UEs.

[00112] In some examples, the BS 243 may determine to perform direct path release. The BS 243 may transmit the RRC reconfiguration message which includes a path switching configuration (e.g. *sl-PathSwitchConfig*).

[00113] As defined in release 17, "*sl-PathSwitchConfig*" is specified for the path switching case from direct-to-indirect or indirect-to-indirect. In some examples, "*sl-PathSwitchConfig*" may include an identifier of a target relay UE and a corresponding value of the first timer. For example, the identifier of a target relay UE may be a L2 source ID of the target relay UE. For example, a value of a first timer T420 may be mandatory in "*sl-PathSwitchConfig*". As defined in release 18 for multi-path case, 'direct path release' (PCell change from direct path to indirect path) is realized by direct-to-indirect path switch

procedure (i.e. *sl-PathSwitchConfig* and *sl-indirectPathMaintain* included in the RRC Reconfiguration message). The “*sl-indirectPathMaintain*” may be used to indicate that the relay UE should keep the PC5 connection with its connected relay UE during the path switching.

5 **[00114]** In the present disclosure, the RRC reconfiguration message includes a path switching configuration (e.g. *sl-PathSwitchConfig*) which includes a value for the first timer (e.g. T420) for path switching. The RRC reconfiguration message also includes an indication of keeping current PC5 connection. For example, the RRC reconfiguration message includes *sl-indirectPathMaintain*.

10 **[00115]** The first UE 241 may ignore the first timer included in the RRC reconfiguration message. Specifically, the first UE 241 may ignore the received value for the first timer (i.e. T420) if the indication of keeping current PC5 connection (e.g. *sl-IndirectPathMaintain*) is included. In some examples, the first UE 241 may perform the path switching procedure in which the direct path is released, based on the RRC reconfiguration message.

15 **[00116]** As such, the value of the first timer, i.e. T420, can be ignored if the indication of keeping current PC5 connection is included. Therefore, the path switching procedure can be simplified without releasing the current indirect path.

20 **[00117]** In some implementations of the process 400, the configuration may include a second timer for indirect path addition or change. For example, the second timer may be represented as T421, however, it is to be understood that the second timer may be in a different form, and the present disclosure does not limit for this aspect.

25 **[00118]** In some example embodiments, the first UE 241 may be configured with multi-path, and the first UE 241 may transmit a measurement report which includes measurement results of one or more candidate relay UEs.

30 **[00119]** In some examples, the BS 243 may determine to perform path switching towards a candidate relay UE. For example, the candidate relay UE may also be referred to as a target relay UE which is associated with a target indirect path. For example, the BS 243 may determine to perform path switching towards the target indirect path. The BS 243 may transmit the RRC reconfiguration message which includes an indication of indirect path addition or change, e.g. “*sl-IndirectPathAddChange*”. For example, the RRC reconfiguration message does not include an indication of keeping the current indirect path, that is, “*sl-IndirectPathMaintain*” is not included. The *sl-IndirectPathAddChange* specifies

the configuration information for indirect path addition/change in multi-path.

[00120] In some examples, the first UE 241 may start the second timer for indirect path addition or change (e.g. T421) upon a reception of the RRC reconfiguration message including *sl-IndirectPathAddChange*, where *sl-IndirectPathMaintain* is not included in *reconfigurationWithSync*.

[00121] In some examples, the first UE 241 may start the second timer for indirect path addition or change (e.g. T421) upon a reception of the RRC reconfiguration message including *sl-IndirectPathAddChange*, where *reconfigurationWithSync* is not included.

[00122] For example, a definition for the second timer (T421) may be updated as that shown in Table 1:

Table 1: T421

T421	Upon reception of the <i>RRCReconfiguration</i> message including <i>sl-IndirectPathAddChange</i> , where <i>sl-IndirectPathMaintain</i> is not included in <i>reconfigurationWithSync</i>	Upon successfully sending <i>RRCReconfigurationComplete</i> message (i.e., PC5 RLC acknowledgement is received from target L2 U2N Relay UE) if split SRB1 with duplication is configured	Perform the Failure Information Reporting as specified in 5.7.3c.
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[00123] In some implementations of the process 400, the configuration may include a first timer for path switching towards a candidate relay UE. For example, the first timer may be represented as T420, however, it is to be understood that the first timer may be in a different form, and the present disclosure does not limit for this aspect.

[00124] In some example embodiments, the first UE 241 access the serving cell via a single path, which may be a direct path or an indirect path.

[00125] In some examples, the BS 243 may determine to perform path switching towards a candidate relay UE. For example, the candidate relay UE may also be referred to as a target relay UE which is associated with a target indirect path. For example, the BS 243 may determine to perform path switching towards the target indirect path. The BS 243 may transmit the RRC reconfiguration message which includes a path switching configuration

(e.g. *sl-PathSwitchConfig*). For example, the RRC reconfiguration message does not include an indication of keeping the current indirect path, that is, “*sl-IndirectPathMaintain*” is not included.

[00126] The IE “*sl-PathSwitchConfig*” is used for direct-to-indirect or indirect-to-indirect path switching, which indicates the L2 source ID of the target Relay UE and the corresponding timer value of the first timer. The IE “*sl-IndirectPathMaintain*” is used to indicate that the relay UE should keep the PC5 connection with its connected relay UE during the path switching.

[00127] The first UE 241 may start the first timer (T420) for path switching upon a reception of the RRC reconfiguration message which includes a path switching configuration (e.g. *sl-PathSwitchConfig*) but does not include an indication of keeping the current indirect path (e.g. *sl-IndirectPathMaintain*).

[00128] In addition, the first UE 241 may stop the first timer upon successfully sending an RRC Reconfiguration Complete message. For example, in response to a PC5 RLC acknowledgement being received from the target relay UE, the first UE 241 may stop the first timer.

[00129] For example, a definition for the first timer (T420) may be updated as that shown in Table 2

Table 2: T420

T420	Upon reception of the <i>RRCReconfiguration</i> message including <i>sl-PathSwitchConfig</i> , where <i>sl-IndirectPathMaintain</i> is not included in <i>reconfigurationWithSync</i>	Upon successfully sending <i>RRCReconfigurationComplete</i> message (i.e., PC5 RLC acknowledgement is received from target L2 U2N Relay UE)	Perform the RRC re-establishment procedure as specified in 5.3.7.
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[00130] According to some embodiments in the present disclosure, a mechanism for multi-path is enhanced for the case that the LTM is supported by the relay UE. In some embodiments, the measurement results of a relay UE and one or more candidate relay UEs may be included in a second message, after the remote UE receives a first message from the relay UE. For example, the first message may be a PC5 unicast link release message and the second message may be a SUI message. In some embodiments, the second message may be an indirect path failure information message which includes a failure type, for

example, a new failure type may be defined. In some embodiments, the remote UE may stop the timer for performing indirect path change in multi-path, if it is running after the remote UE initiates re-establishment procedure. In some embodiments, a new condition is proposed to start the timer for performing path switching towards a target indirect path. In some embodiments, a new condition is proposed to start the timer for performing indirect path change in multi-path.

[00131] According to some embodiments discussed with reference to FIGS. 3-4, a mechanism for an indirect path or a multi-path scenario is proposed, therefore, UE behavior is defined and a U2N communication is guaranteed.

[00132] FIG. 5 illustrates an example of a device 500 that is suitable for implementing embodiments of the present disclosure. The device 500 may be an example of a UE as described herein. The device 500 may support wireless communication with the first UE 241, the second UE 242, the BS 243, or any combination thereof. The device 500 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 502, a memory 504, a transceiver 506, and, optionally, an I/O controller 508. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[00133] The processor 502, the memory 504, the transceiver 506, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 502, the memory 504, the transceiver 506, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[00134] In some implementations, the processor 502, the memory 504, the transceiver 506, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to perform one or more of the functions described herein (e.g.,

executing, by the processor 502, instructions stored in the memory 504).

[00135] For example, the processor 502 may support wireless communication at the device 500 in accordance with examples as disclosed herein. The processor 502 may be configured to operable to support a means for actions discussed above.

5 **[00136]** The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 502 may be configured to operate a memory array using a memory controller. In some other
10 implementations, a memory controller may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 504) to cause the device 500 to perform various functions of the present disclosure.

[00137] The memory 504 may include random access memory (RAM) and read-only
15 memory (ROM). The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 502 cause the device 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 502 but may cause
20 a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 504 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[00138] The I/O controller 508 may manage input and output signals for the device 500.
25 The I/O controller 508 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 508 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 508 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller
30 508 may be implemented as part of a processor, such as the processor 506. In some implementations, a user may interact with the device 500 via the I/O controller 508 or via hardware components controlled by the I/O controller 508.

[00139] In some implementations, the device 500 may include a single antenna 510. However, in some other implementations, the device 500 may have more than one antenna 510 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 506 may communicate bi-directionally, via the one or more antennas 510, wired, or wireless links as described herein. For example, the transceiver 506 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 506 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 510 for transmission, and to demodulate packets received from the one or more antennas 510. The transceiver 506 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[00140] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 510 for transmitting the amplified signal into the air or wireless medium.

[00141] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 510 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[00142] FIG. 6 illustrates an example of a processor 600 that is suitable for implementing some embodiments of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described

herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[00143] The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[00144] The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[00145] The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor

600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data within the processor 600. The controller 602 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor
5 600.

[00146] The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the
10 memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

[00147] The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602
15 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple
20 processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[00148] The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more
25 ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which
30 determines an operation to be executed. One or more ALUs 606 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 606 may support logical operations such as AND, OR,

exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

[00149] The processor 600 may support wireless communication in accordance with examples as disclosed herein. The processor 600 may be configured to or operable to support a means for operations described in some embodiments of the present disclosure.

[00150] FIG. 7 illustrates a flowchart of a method 700 performed by a first UE in accordance with aspects of the present disclosure. The operations of the method 700 may be implemented by a device or its components as described herein. For example, the operations of the method 700 may be performed by the first UE 241 in FIG. 2D. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00151] At 710, the method may include receiving, from a second UE, a first message comprising a notification message or a release message, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE. The operations of 710 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 710 may be performed by the first UE 241 as described with reference to FIG. 2D.

[00152] At 720, the method may include transmitting, to the base station via the direct path, based on the first message, a second message comprising measurement results of the second UE and at least one candidate relay UE. The operations of 720 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 720 may be performed by the first UE 241 as described with reference to FIG. 2D.

[00153] FIG. 8 illustrates a flowchart of a method 800 performed by a second UE in accordance with aspects of the present disclosure. The operations of the method 800 may be implemented by a device or its components as described herein. For example, the operations of the method 800 may be performed by the second UE 242 in FIG. 2D. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00154] At 810, the method may include determining that an LTM of the second UE occurs. The operations of 810 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 810 may be performed by the second UE 242 as described with reference to FIG. 2D.

5 [00155] At 820, the method may include transmitting, to a first UE, a first message comprising a notification message or a release message indicating the LTM of the second UE, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second UE. The operations of 820 may be performed in accordance with examples as described herein. In
10 some implementations, aspects of the operations of 820 may be performed by the second UE 242 as described with reference to FIG. 2D.

[00156] FIG. 9 illustrates a flowchart of a method 900 performed by a first UE in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a device or its components as described herein. For example, the
15 operations of the method 900 may be performed by the first UE 241 in FIG. 2D. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00157] At 910, the method may include receiving, from a base station, a configuration
20 comprising a first timer for path switching towards a candidate relay UE or a second timer for indirect path addition or change, wherein the first UE is configured with a direct path between the first UE and the base station and an indirect path between the first UE and the base station via a second UE. The operations of 910 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 910
25 may be performed by the first UE 241 as described with reference to FIG. 2D.

[00158] At 920, the method may include in accordance with a determination that a condition is met, performing one of: stopping the second timer; or ignoring the first timer. The operations of 920 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 920 may be performed by the first UE
30 241 as described with reference to FIG. 2D.

[00159] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise

modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[00160] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00161] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[00162] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[00163] As used herein, including in the claims, an article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of

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

[00164] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be
15 applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A first user equipment (UE) comprising:
at least one memory; and
5 at least one processor coupled with the at least one memory and configured to cause the first UE to:
receive, from a second UE, a first message comprising a notification message or a release message, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE and the base station via the second
10 UE; and
transmit, to the base station via the direct path, based on the first message, a second message comprising measurement results of the second UE and at least one candidate relay UE.
- 15 2. The first UE of claim 1, wherein the notification message comprises an indication type, and the indication type indicates an LTM of the second UE or a handover of the second UE.
- 20 3. The first UE of claim 1, wherein the release message comprises a proximity communication 5 (PC5) unicast link release message with a failure type, and the failure type indicates the LTM of the second UE or a handover of the second UE.
- 25 4. The first UE of claim 1, wherein the second message comprises a sidelink UE information (SUI) message, and the SUI message comprises measurement results of the first UE and the second UE.
5. The first UE of claim 1, wherein the second message comprises an SUI message and the SUI message comprises a cause value indicating a PC5-S release or other failure.
- 30 6. The first UE of claim 1, wherein the second message comprises an indirect path failure information message with a failure type, wherein the failure type indicates the LTM of the second UE or a handover of the second UE.

7. A second user equipment (UE) comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the second UE to:
- 5 determine that a layer 1 or layer 2 triggered mobility (LTM) of the second UE occurs;
and
transmit, to a first UE, a first message comprising a notification message or a release message indicating the LTM of the second UE, wherein the first UE is configured with a direct path between the first UE and a base station and an indirect path between the first UE
10 and the base station via the second UE.
8. The second UE of claim 7, wherein the notification message comprises an indication type, and the indication type indicates an LTM of the second UE or a handover of the second UE.
- 15
9. The second UE of claim 8, wherein the LTM of the second UE is determined upon an indication from a lower layer of the second UE, and wherein the indication indicates that an LTM cell switch procedure is triggered.
- 20
10. The second UE of claim 8, wherein the LTM of the second UE is determined upon a reception of an LTM cell switch command.
11. The second UE of claim 8, wherein the LTM of the second UE is determined upon performing an LTM cell switch procedure following a cell selection procedure which
25 is performed while a timer T311 is running.
12. The second UE of claim 7, wherein the release message comprises a proximity communication 5 (PC5) unicast link release message with a failure type, and the failure type indicates the LTM of the second UE or a handover of the second UE.
- 30
13. The second UE of claim 12, wherein the LTM of the second UE is determined based on an indication from an access stratum (AS) layer to an upper layer, and wherein the indication indicates an LTM of the second UE.

14. A first user equipment (UE) comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the first UE to:

5 receive, from a base station, a configuration comprising a first timer for path switching towards a candidate relay UE or a second timer for indirect path addition or change, wherein the first UE is configured with a direct path between the first UE and the base station and an indirect path between the first UE and the base station via a second UE;
in accordance with a determination that a condition is met, perform one of:
10 stopping the second timer; or
ignoring the first timer.

15 15. The first UE of claim 14, wherein the at least one processor is further configured to cause the first UE to:

start the second timer upon a reception of a radio resource control (RRC) reconfiguration message for indirect path change, wherein RRC reconfiguration message does not include an indication of keeping the indirect path or does not include reconfiguration with synchronization.

20 16. The first UE of claim 14, wherein the condition associated with stopping the second timer comprises one of:

a detection of a radio link failure of a master cell group while the indirect path change is ongoing, or

an initiation of a re-establishing procedure while the indirect path change is ongoing.

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17. The first UE of claim 14, wherein the configuration comprises a path switching configuration, and wherein the condition associated with ignoring the first timer comprises an indication of keeping a current PC5 connection which is included in the configuration.

30