

UPLINK DATA SPLIT TRIGGERED BY DELAY STATUS

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to user equipment (UE), base station and methods for supporting uplink (UL) data split triggered by delay status.

BACKGROUND

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

[0003] Currently, in dual connectivity (DC), for a split bearer, a packet data convergence protocol (PDCP) entity of a user equipment (UE) is associated with two radio link control (RLC) entities, i.e., a primary RLC entity and a split secondary RLC entity. A split bearer may be defined as below: in dual connectivity, a bearer whose radio protocols are located in both a master gNB (MgNB) and a secondary gNB (SgNB) to use both MgNB and SgNB resources. A split secondary RLC entity may be defined as below: in dual connectivity, the RLC entity other than the primary RLC entity which is responsible for split bearer operation. If the PDCP entity is associated with two RLC entities, the split secondary RLC entity is the RLC entity other than the primary RLC entity. If the PDCP entity is associated with more than two RLC entities, the split secondary RLC entity is configured by upper layers.

SUMMARY

[0004] The present disclosure relates to UE and methods that support UL data split triggered by delay status. With the UE and methods, delay status information is considered for PDCP routing, e.g., for selecting only a primary path or both the primary path and a secondary path for UL data transmission of a split bearer.

[0005] Some implementations of a UE described herein may include a processor and a transceiver coupled to the processor, wherein the processor is configured to: receive, via the transceiver from one of a first base station and a second base station, at least one UL split threshold associated with delay status for a UL split bearer; and based on the at least one UL split threshold, use both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

[0006] In some implementations, the at least one UL split threshold comprises a first UL split threshold for remaining time associated with delay status; and the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer: based on determining that the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0007] In some implementations, the at least one UL split threshold comprises a second UL split threshold for data volume associated with the delay status; and the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by: based on determining that data volume associated with the delay status is larger than or equal to the second UL split threshold for data volume, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0008] In some implementations, the at least one UL split threshold comprises a first UL split threshold for remaining time associated with delay status and a second UL split threshold for data volume associated with the delay status; and the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by: based on determining that the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time and that data volume associated with the delay status is larger than or equal to the second UL split threshold

for data volume, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0009] In some implementations, the data volume associated with the delay status comprises one of the following: first data volume of a first set of packets associated with the primary path, wherein remaining time of the first set of packets is less than or equal to a threshold for triggering reporting of a DSR, second data volume of a second set of packets associated with the secondary path, wherein remaining time of the second set of packets is less than or equal to the threshold for triggering the reporting of the DSR, or a sum of the first data volume and the second data volume.

[0010] In some implementations, the at least one UL split threshold comprises a third UL split threshold; and the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by: based on determining that a total amount of first data volume pending for transmission in a PDCP entity of the UE and second data volume pending for initial transmission in the primary RLC entity and the split secondary RLC entity of the UE is equal to or larger than the third UL split threshold, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0011] In some implementations, the processor is further configured to transmit, via the transceiver to the first base station and the second base station, a first DSR of the UL split bearer and a second DSR of the UL split bearer through the primary path and the secondary path, respectively, wherein the first DSR is associated with the primary path, and the second DSR is associated with the secondary path.

[0012] In some implementations, the processor is further configured to: based on determining that the smallest remaining time of UL data associated with the primary path is less than or equal to a first threshold for triggering reporting of the first DSR, trigger the reporting of the first DSR; and the UL data associated with the primary path comprises at least one of the following: PDCP SDUs or PDCP PDUs to be routed to the primary RLC entity or to be routed to both the primary RLC entity and the split secondary RLC entity; and RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity.

[0013] In some implementations, the UL data associated with the primary path comprises a first set of packets associated with the primary path, the first DSR comprises

data volume of the first set of packets, and remaining time of the first set of packets is less than or equal to the first threshold for triggering reporting of the first DSR.

[0014] In some implementations, the processor is further configured to: based on determining that the smallest remaining time of UL data associated with the secondary path is less than or equal to a second threshold for triggering reporting of the second DSR, trigger the reporting of the second DSR; and the UL data associated with the secondary path comprises at least one of the following: PDCP SDUs or PDCP PDUs to be routed to the split secondary RLC entity or to be routed to both the primary RLC entity and the split secondary RLC entity; and RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity.

[0015] In some implementations, the UL data associated with the secondary path comprises a second set of packets associated with the secondary path, the second DSR comprises data volume of the second set of packets, and remaining time of the second set of packets is less than or equal to the second threshold for triggering reporting of the second DSR.

[0016] In some implementations, the processor is further configured to: transmit, via the transceiver to the first base station and the second base station, a DSR of the UL split bearer through the primary path and the secondary path, respectively, wherein the DSR is associated with both the primary path and the secondary path.

[0017] In some implementations, the processor is further configured to: based on determining that smallest remaining time of UL data associated with both the primary path and the secondary path is less than or equal to a threshold for triggering reporting of the DSR, trigger the reporting of the DSR; and the UL data associated with both the primary path and the secondary path comprises at least one of the following: PDCP SDUs or PDCP PDUs to be transmitted; and RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity and the split secondary RLC entity.

[0018] In some implementations, the UL data associated with both the primary path and the secondary path comprises a third set of packets associated with both the primary path and the secondary path, the DSR comprises data volume of the third set of packets, and remaining time of the third set of packets is less than or equal to the threshold for triggering reporting of the DSR.

[0019] In some implementations, the third set of packets comprises a first subset of packets in the primary RLC entity, a second subset of packets in the split secondary RLC entity and a third subset of packets in a PDCP entity of the UE.

[0020] In some implementations, the processor is further configured to: provide first data volume of the first subset of packets from the primary RLC entity to a second media access control (MAC) entity of the UE associated with the split secondary RLC entity; provide second data volume of the second subset of packets from the split secondary RLC entity to a first MAC entity of the UE associated with the primary RLC entity; and provide third data volume of the third subset of packets from the PDCP entity to the first MAC entity and the second MAC entity, respectively.

[0021] In some implementations, the processor is further configured to: provide first data volume of the first subset of packets from a first media access control (MAC) entity of the UE associated with the primary RLC entity to a second MAC entity of the UE associated with the split secondary RLC entity; provide second data volume of the second subset of packets from the second MAC entity to the first MAC entity; and provide third data volume of the third subset of packets from the PDCP entity to the first MAC entity and the second MAC entity, respectively.

[0022] In some implementations, the processor is further configured to: receive, via the transceiver from one of the first base station and the second base station, an indication indicating that the secondary path is used for at least one protocol data unit (PDU) Set with at least one value of PDU Set Importance (PSI); and the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by: using the secondary path for UL data transmission of the at least one PDU Set with the at least one value of PSI based on the indication.

[0023] In some implementations, the processor is further configured to: transmit, via the transceiver to the first base station and the second base station, a first DSR of the UL split bearer and a second DSR of the UL split bearer through the primary path and the secondary path, respectively, wherein the first DSR is associated with the primary path, and the second DSR is associated with the secondary path.

[0024] In some implementations, the processor is further configured to: based on determining that smallest remaining time of UL data associated with the secondary path is less than or equal to a second threshold for triggering reporting of the second DSR

trigger the reporting of the second DSR; and the UL data associated with the secondary path comprises the at least one PDU Set.

[0025] In some implementations, the processor is further configured to: receive, via the transceiver from the base station, at least one threshold for triggering PDCP duplication; based on the at least one threshold, duplicate a PDCP PDU; and use a primary path associated with a primary RLC entity of the UE for UL transmission of the PDCP PDU and a secondary path associated with a split secondary RLC entity of the UE for UL transmission of the duplicated PDCP PDU.

[0026] In some implementations, the at least one threshold comprises a third threshold for remaining time associated with delay status; and the processor is configured to use the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU by: based on determining that the smallest remaining time of UL data is less than or equal to the third threshold for remaining time, using the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU.

[0027] In some implementations, the at least one threshold comprises a fourth threshold for data volume associated with the delay status; and the processor is configured to use the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU by: based on determining that data volume associated with the delay status is larger than or equal to the fourth threshold for data volume, using the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU.

[0028] In some implementations, the at least one threshold comprises a third threshold for remaining time associated with delay status and a fourth threshold for data volume associated with the delay status; and the processor is configured to use the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU by: based on determining that remaining time of UL data is less than or equal to the third threshold for remaining time and that data volume associated with the delay status is larger than or equal to the fourth threshold for data volume, using the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU.

[0029] Some implementations of a method described herein may include: receiving, at a UE from one of a first base station and a second base station, at least one UL split threshold associated with delay status for a UL split bearer; and based on the at least one UL split threshold, using both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

[0030] Some implementations of a processor described herein may include at least one memory and a controller coupled with the at least one memory and configured to cause the controller to: receive, from one of a first base station and a second base station, at least one UL split threshold associated with delay status for a UL split bearer; and based on the at least one UL split threshold, use both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

[0031] It is to be understood that the summary section is not intended to identify key or essential features of embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Figs. 1A and 1B illustrate an example of a wireless communications system that supports UL data split triggered by delay status in accordance with aspects of the present disclosure, respectively;

[0033] Fig. 1C illustrates an example of UL data split triggered by delay status in accordance with aspects of the present disclosure;

[0034] Figs. 2 to 5 illustrate a signaling diagram illustrating an example process that supports UL data split triggered by delay status in accordance with aspects of the present disclosure, respectively;

[0035] Fig. 6 illustrates a signaling diagram illustrating an example process that supports PDCP duplication triggered by delay status in accordance with aspects of the present disclosure;

[0036] Fig. 7 illustrates an example of a device that supports UL data split and/or PDCP duplication triggered by delay status in accordance with some aspects of the present disclosure;

[0037] Fig. 8 illustrates an example of a processor that supports UL data split and/or PDCP duplication triggered by delay status in accordance with aspects of the present disclosure; and

[0038] Fig. 9 illustrates a flowchart of a method that supports UL data split triggered by delay status in accordance with aspects of the present disclosure.

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 disclosure described herein may be implemented in various manners other than the ones described below.

[0040] 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.

[0041] References in the present disclosure to “one embodiment,” “an example embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0042] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a

second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms.

[0043] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0044] As described above, in dual connectivity, for a split bearer, a PDCP entity of a UE is associated with the primary RLC entity and the split secondary RLC entity.

[0045] In legacy, for UL data transmission and BSR report of a split bearer, a threshold is configured. If the total amount of data volume in PDCP entity and RLC entity is equal to or larger than the threshold, the UE shall use both the primary path and the secondary path for UL data transmission of the split bearer. Otherwise, only the primary path is used for UL data transmission of the split bearer.

[0046] Specifically, for UL data transmission of a split bearer, if the total amount of PDCP data volume and RLC data volume pending for initial transmission in the primary RLC entity and the split secondary RLC entity is equal to or larger than *ul-DataSplitThreshold*, the PDCP entity of the UE shall submit a PDCP PDU to either the primary RLC entity or the split secondary RLC entity. Otherwise, the UE submits the PDCP PDU to the primary RLC entity.

[0047] For BSR report of a split bearer, if the total amount of PDCP data volume and RLC data volume pending for initial transmission in the primary RLC entity and the split secondary RLC entity is equal to or larger than *ul-DataSplitThreshold*, the UE indicates the PDCP data volume to both the medium access control (MAC) entity associated with the primary RLC entity and the MAC entity associated with the split secondary RLC entity. Otherwise, the UE indicates the PDCP data volume to the MAC entity associated with the primary RLC entity.

[0048] A DSR reporting procedure may be used to provide a base station with delay status of UL data. This delay status may include remaining time (RT) of UL data, which is based on a value of its associated timer at the time of the first symbol of the physical uplink control channel (PUSCH) transmission in which the DSR is transmitted. The DSR reporting procedure may be also used to provide the base station with the amount of UL data associated with the reported remaining time. The DSR reporting may improve the UL scheduling.

[0049] It has been agreed that a new separate MAC control element (CE) may be defined for DSR reporting. For example, DSR reporting is not coupled with BSR reporting.

[0050] For an NR-DC UL split bearer, the UE transmitted the UL data via the primary path initially. In some case, for example, when the UL congestion occurs in a primary path, the UE needs to start to transmit the UL data via a secondary path when the remaining time of UL data is approximately running out. In other words, the UE needs to consider delay status information for PDCP routing, e.g., for selecting only the primary path or both the primary path and the secondary path for UL data transmission of a split bearer.

[0051] In view of the above, the present disclosure provides a solution that supports UL data split triggered by delay status. In this solution, a UE receives, from a base station, at least one UL split threshold associated with delay status for a UL split bearer. Based on the at least one UL split threshold, the UE uses both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer. With this solution, the UE considers delay status information for PDCP routing, e.g., for selecting only the primary path or both the primary path and the secondary path for UL data transmission of a split bearer.

[0052] Aspects of the present disclosure are described in the context of a wireless communications system.

[0053] Fig. 1A illustrates an example of a wireless communications system 100A that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The wireless communications system 100A may include one at least one of network entities 102 (also referred to as network equipment (NE)), one or more terminal

devices or UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100A may support various radio access technologies. In some implementations, the wireless communications system 100A may be a 4G network, such as an LTE network or an LTE-advanced (LTE-A) network. In some other implementations, the wireless communications system 100A may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100A may be a combination of a 4G network and a 5G network, or other suitable radio access technology including institute of electrical and electronics engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100A may support radio access technologies beyond 5G. Additionally, the wireless communications system 100A may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0054] The network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100A. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station (BS), a network element, a radio access network (RAN) node, a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Hereinafter, some implementations of the present disclosure will be described by taking base stations as an example of the network entities 102. Thus, a network entity 102 may be used interchangeably with a base station 102. For example, the base stations 102 may comprise a first base station 102-1 and a second base station 102-2.

[0055] A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0056] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.)

according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0057] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100A. 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 100A. In some other implementations, a UE 104 may be mobile in the wireless communications system 100A.

[0058] 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. 1A. 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. 1A. 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 100A.

[0059] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V)

deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0060] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0061] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open radio access network (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN intelligent controller (RIC) (e.g., a near-real time RIC (Near-RT RIC), a non-real time RIC (Non-RT RIC)), a service management and orchestration (SMO) system, or any combination thereof.

[0062] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one

or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0063] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., radio resource control (RRC), service data adaptation protocol (SDAP), packet data convergence protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0064] 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).

[0065] 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.

[0066] 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.

[0067] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0068] In the wireless communications system 100A, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100A (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0069] One or more numerologies may be supported in the wireless communications system 100A, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0070] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0071] 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 100A. 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.

[0072] In the wireless communications system 100A, 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 100A may support one or multiple operating frequency bands, such as frequency range designations FR1 (510 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0073] 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.

[0074] Fig. 1B illustrates an example of a wireless communications system 100B that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. In the wireless communications system 100B, initially, the UE 104 may transmit UL data via a primary path between the UE 104 and the first base station 102-1. For example, when the UL congestion occurs in the primary path, UL data split is triggered based on at least one UL split threshold associated with delay status for a UL split bearer. Such kind of UL data split is referred to as UL data split triggered by delay status or delay status triggered UL data split. In other words, based on the at least one UL

split threshold, the UE 104 uses both the primary path and a secondary path between the UE 104 and the second base station 102-2 for UL data transmission of a UL split bearer. Hereinafter, UL data split is also referred to as UL split for brevity.

[0075] In some implementations, the first base station 102-1 may act as an MgNB and the second base station 102-2 may act as an SgNB. Alternatively, the first base station 102-1 may act as the SgNB and the second base station 102-2 may act as the MgNB.

[0076] Fig. 1C illustrates an example of UL data split triggered by delay status in accordance with aspects of the present disclosure.

[0077] As shown in Fig. 1C, the UE 104 may comprise a PDCP entity 120, an RLC entity 130 (also referred to as a primary RLC entity 130) and a MAC entity 140. The MAC entity 140 is associated with the primary RLC entity 130. A primary path between the UE 104 and the first base station 102-1 is associated with the primary RLC entity 130. Initially, the UE 104 may transmit UL data via a primary path between the UE 104 and the first base station 102-1.

[0078] For example, when the UL congestion occurs in the primary path, UL split is triggered based on at least one UL split threshold associated with delay status for a UL split bearer. In other words, based on the at least one UL split threshold, the UE 104 uses both the primary path and a secondary path between the UE 104 and the second base station 102-2 for UL data transmission of a UL split bearer. The secondary path is associated with a split secondary RLC entity 132. A MAC entity 142 is associated with the split secondary RLC entity 132.

[0079] Fig. 2 illustrates a signaling diagram illustrating an example process 200 that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The process 200 may involve the UE 104 and the first base station 102-1 or the second base station 102-2 in Fig. 1A or 1B. For the purpose of discussion, the process 200 will be described with reference to Fig. 1A, 1B or 1C.

[0080] As shown in Fig. 2, the UE 104 receives 210 a configuration of data radio bearer (DRB) from the first base station 102-1 or the second base station 102-2. The configuration of DRB may indicate that the DRB is configured as a UL split DRB in NR-DC.

[0081] In some implementations, the first base station 102-1 may act as an MgNB and the second base station 102-2 may act as an SgNB. Alternatively, the first base station 102-1 may act as the SgNB and the second base station 102-2 may act as the MgNB.

[0082] In some implementations, the first base station 102-1 or the second base station 102-2 may indicate a primary path and a secondary path of the UL split DRB. Information about the primary path may comprise information indicating a cell group ID and LCID of the primary RLC entity 130. Information about the secondary path may indicate the LCID of the split secondary RLC entity 132, and this RLC entity belongs to a cell group that is different from the cell group for the primary path.

[0083] In some implementations, a split bearer may be defined as below: in dual connectivity, a bearer whose radio protocols are located in both the MgNB (or master cell group (MCG)) and the SgNB (or secondary cell group (SCG)) to use both MgNB and SgNB resources. For a split bearer, the PDCP entity 120 of the UE 104 is associated with two RLC entities, i.e., the primary RLC entity 130 and the split secondary RLC entity 132.

[0084] The UE 104 receives 220, from the first base station 102-1 or the second base station 102-2, at least one UL split threshold associated with delay status for a UL split bearer.

[0085] In turn, the UE 104 triggers 230 UL split based on the at least one UL split threshold. In other words, based on the at least one UL split threshold, the UE 104 uses both a primary path associated with the primary RLC entity 130 and a secondary path associated with the split secondary RLC entity 132 for UL data transmission of the UL split bearer.

[0086] With the process 200, the UE 104 considers delay status information for PDCP routing, e.g., for selecting only the primary path or both the primary path and the secondary path for UL data transmission of a split bearer.

[0087] In some implementations, the at least one UL split threshold associated with delay status may comprise a first UL split threshold for remaining time associated with delay status.

[0088] In some implementations, the first UL split threshold for remaining time may be an enumerated value e.g., 3ms.

[0089] In some implementations, the first UL split threshold for remaining time may be the same as or different from a threshold for triggering reporting of a DSR.

[0090] In some implementations, if the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time, the UE 104 uses both the primary path and the secondary path for UL data transmission of the UL split bearer. Otherwise, the UE 104 only uses the primary path for UL data transmission for the split bearer. For example, if the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time, the PDCP entity 120 submits a PDCP PDU to either the primary RLC entity 130 or the split secondary RLC entity 132. Otherwise, the PDCP entity 120 submits the PDCP PDU to the primary RLC entity 130.

[0091] In some implementations, the UL data may comprise at least one of the following:

- PDCP SDUs for which no PDCP PDUs have been constructed,
- PDCP PDUs that have not been submitted to lower layers of the PDCP entity, or
- RLC SDUs or RLC PDUs to be transmitted.

[0092] In some implementations, the RLC SDUs or RLC PDUs to be transmitted may comprise at least one of the following:

- RLC SDUs and RLC SDU segments that have not been included in an RLC PDU, wherein an RLC SDU segment may be a segment of an RLC SDU,
- RLC PDUs that are pending for initial transmission, or
- RLC PDUs that are pending for retransmission (RLC Acknowledged Mode (AM)).

[0093] In some implementations, remaining time of a packet is a value of a PDCP discard timer (configured by RRC) minus the running time of the PDCP discard timer. The PDCP discard timer is started upon reception of a PDCP SDU associated with a packet from upper layer of the UE 104. Usually, the value of the PDCP discard timer is set according to packets delay budget (PDB) or PDU set delay budget (PSDB). When the PDCP discard timer expires, the UE 104 shall discard the PDCP SDU.

[0094] Consider an example. In this example, the value of the PDCP discard timer is equal to 50ms. The first UL split threshold for remaining time is equal to 15ms.

[0095] In this example, the UL data comprises packet#1 (RT=12ms), packet#2 (RT=13ms), packet#3 (RT=20ms) and packet#4 (RT=18ms). Because the remaining time of packet#1 is the smallest among the remaining time of packet#1, packet#2, packet#3 and packet#4, the smallest remaining time of the UL data is equal to the remaining time of packet#1. Because the smallest remaining time of the UL data is less than the first UL split threshold for remaining time, the UE 104 triggers the UL split.

[0096] Alternatively, in some implementations, the at least one UL split threshold may comprise a second UL split threshold for data volume associated with the delay status. If data volume associated with the delay status is larger than or equal to the second UL split threshold for data volume, the UE 104 may use both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0097] Alternatively, in some implementations, the at least one UL split threshold may comprise a first UL split threshold for remaining time associated with delay status and a second UL split threshold for data volume associated with the delay status. If the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time and that data volume associated with the delay status is larger than or equal to the second UL split threshold for data volume, the UE 104 may use both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0098] In some implementations, the data volume associated with the delay status may comprise one of the following:

- first data volume of a first set of packets associated with the primary path, wherein remaining time of the first set of packets is less than or equal to a threshold for triggering reporting of a DSR,
- second data volume of a second set of packets associated with the secondary path, wherein remaining time of the second set of packets is less than or equal to the threshold for triggering the reporting of the DSR, or
- a sum of the first data volume and the second data volume.

[0099] In some implementations, the at least one UL split threshold may comprise a third UL split threshold. The third UL split threshold may indicate a threshold value for UL data split operation. If a total amount of first data volume pending for transmission in the PDCP entity 120 and second data volume pending for initial transmission in the primary RLC entity 130 and the split secondary RLC entity 132 is equal to or larger than the third UL split threshold, the UE 104 may use both the primary path and the secondary path for UL data transmission of the UL split bearer.

[0100] In some implementations, the third UL split threshold may be configured by *ul-DataSplitThreshold*. For example, *ul-DataSplitThreshold* may be configured as below:

```
UL-DataSplitThreshold ::= ENUMERATED {
    b0, b100, b200, b400, b800, b1600, b3200,
    b6400, b12800, b25600, b51200, b102400, b204800,
    b409600, b819200, b1228800, b1638400,
    b2457600, b3276800, b4096000, b4915200, b5734400,
    b6553600, infinity, spare8, spare7, spare6,
    spare5, spare4, spare3, spare2, spare1}
```

where value b0 corresponds to 0 bytes, value b100 corresponds to 100 bytes, value b200 corresponds to 200 bytes, and so on. The base station 102 sets this field to infinity for UEs not supporting *splitDRB-withUL-Both-MCG-SCG* and when the SCG is deactivated. If the field is absent when the split bearer is configured for the radio bearer first time, then the default value infinity is applied.

[0101] In some implementations, DSRs of the primary path and the secondary path have different triggers. The first base station 102-1 or the second base station 102-2 configures two independent or separate thresholds for triggering reporting of DSRs. This will be described with reference to Fig. 3.

[0102] Fig. 3 illustrates a signaling diagram illustrating an example process 300 that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The process 300 may be considered as an example implementation of the process 200. The process 300 may involve the UE 104, the first base station 102-1 and the second base station 102-2 in Fig. 1A or 1B. For the purpose of discussion, the process 200 will be described with reference to Fig. 1A, 1B or 1C.

[0103] In the process 300, the first base station 102-1 may act as an MgNB and the second base station 102-2 may act as an SgNB. Alternatively, the first base station 102-1 may act as the SgNB and the second base station 102-2 may act as the MgNB.

[0104] Actions 210, 220 and 230 in the process 300 are similar to those in the process 200. Details of these actions are omitted for brevity.

[0105] The process 300 is different from the process 200 in actions 310 and 320.

[0106] Specifically, the UE 104 transmits 310, to the first base station 102-1, a first DSR of the UL split bearer through the primary path. The first DSR is associated with the primary path.

[0107] In some implementations, if the smallest remaining time of UL data associated with the primary path is less than or equal to a first threshold for triggering reporting of the first DSR, the UE 104 triggers the reporting of the first DSR.

[0108] In some implementations, the UL data associated with the primary path may comprise at least one of the following:

- PDCP SDUs or PDCP PDUs to be routed to the primary RLC entity 130 or to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132, or
- RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity 130.

[0109] In some implementations, the PDCP SDUs to be routed to the primary RLC entity 130 or to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 may comprise PDCP SDUs for which no PDCP PDUs have been constructed.

[0110] In some implementations, the PDCP PDUs to be routed to the primary RLC entity 130 or to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 may comprise PDCP PDUs that have not been submitted to the primary RLC entity 130 or to both the primary RLC entity 130 and the split secondary RLC entity 132.

[0111] In some implementations, the RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity 130 may comprise at least one of the following in the primary RLC entity 130:

- RLC SDUs and RLC SDU segments that have not been included in an RLC PDU, wherein an RLC SDU segment may be a segment of an RLC SDU,
- RLC PDUs that are pending for initial transmission, or
- RLC PDUs that are pending for retransmission (RLC AM).

[0112] In some implementations, the UL data associated with the primary path comprises a first set of packets associated with the primary path. The first DSR comprises data volume of the first set of packets, and remaining time of the first set of packets is less than or equal to the first threshold for triggering reporting of the first DSR.

[0113] Consider a first example. In the first example, a value of a PDCP discard timer is equal to 50ms. Each of the first threshold and the second threshold is equal to 15ms.

[0114] In the first example, PDCP SDUs or PDCP PDUs to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 comprise packet#1 (RT=12ms) and packet#2 (RT=13ms). PDCP SDUs or PDCP PDUs to be routed to the primary RLC entity 130 comprise packet#1 (RT=12ms). RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity 130 comprise packet#3 (RT=20ms). UL data associated with the primary path comprises packet#1 (RT=12ms), packet#2 (RT=13ms) and packet#3 (RT=20ms). The first set of packets associated with the primary path comprises packet#1 (RT=12ms) and packet#2 (RT=13ms). The first DSR comprises data volume of the first set of packets, i.e., data volume of packet#1 (RT=12ms) and packet#2 (RT=13ms).

[0115] Consider a second example. In the second example, a value of a PDCP discard timer is equal to 50ms. Each of the first threshold and the second threshold is equal to 15ms.

[0116] In the second example, PDCP SDUs or PDCP PDUs to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 comprise packet#1 (RT=12ms) and packet#2 (RT=13ms). PDCP SDUs or PDCP PDUs to be routed to the primary RLC entity 130 comprise packet#1 (RT=12ms). RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity 130 comprise packet#3 (RT=20ms). UL data associated with the primary path comprises packet#1 (RT=12ms). The first set of packets associated with the primary path comprises packet#1 (RT=12ms). The first DSR

comprises data volume of the first set of packets, i.e., data volume of packet#1 (RT=12ms).

[0117] With continued reference to Fig. 3, the UE 104 transmits 320, to the second base station 102-2, a second DSR of the UL split bearer through the secondary path. The second DSR is associated with the secondary path.

[0118] In some implementations, if the smallest remaining time of UL data associated with the secondary path is less than or equal to a second threshold for triggering reporting of the second DSR, the UE 104 triggers the reporting of the second DSR. The second threshold for triggering reporting of the second DSR is independent or separate from the first threshold for triggering reporting of the first DSR. A value of the second threshold may be the same as or different from a value of the first threshold.

[0119] In some implementations, the UL data associated with the secondary path may comprise at least one of the following:

- PDCP SDUs or PDCP PDUs to be routed to the split secondary RLC entity 132 or to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132, or
- RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity 132.

[0120] In some implementations, the PDCP SDUs to be routed to the split secondary RLC entity 132 or to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 may comprise PDCP SDUs for which no PDCP PDUs have been constructed.

[0121] In some implementations, the PDCP PDUs to be routed to the split secondary RLC entity 132 or to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 may comprise PDCP PDUs that have not been submitted to the secondary RLC entity 132 or to both the primary RLC entity 130 and the split secondary RLC entity 132.

[0122] In some implementations, the RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity 132 may comprise at least one of the following in the split secondary RLC entity 132:

- RLC SDUs and RLC SDU segments that have not been included in an RLC PDU, wherein an RLC SDU segment may be a segment of an RLC SDU,
- RLC PDUs that are pending for initial transmission, or
- RLC PDUs that are pending for retransmission (RLC AM).

[0123] In some implementations, the UL data associated with the secondary path comprises a second set of packets associated with the secondary path. The second DSR comprises data volume of the second set of packets, and remaining time of the second set of packets is less than or equal to the second threshold for triggering reporting of the second DSR.

[0124] Consider a third example. In the third example, a value of a PDCP discard timer is equal to 50ms. Each of the first threshold and the second threshold is equal to 15ms.

[0125] In the first example, PDCP SDUs or PDCP PDUs to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 comprise packet#1 (RT=12ms) and packet#2 (RT=13ms). PDCP SDUs or PDCP PDUs to be routed to the split secondary RLC entity 132 comprise packet#2 (RT=13ms). RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity 132 comprise packet#4 (RT=18ms). UL data associated with the split secondary path comprises packet#1 (RT=12ms), packet#2 (RT=13ms) and packet#4 (RT=18ms). The second set of packets associated with the secondary path comprises packet#1 (RT=12ms) and packet#2 (RT=13ms). The second DSR comprises data volume of the second set of packets, i.e., data volume of packet#1 (RT=12ms) and packet#2 (RT=13ms).

[0126] Consider a fourth example. In the fourth example, a value of a PDCP discard timer is equal to 50ms. Each of the first threshold and the second threshold is equal to 15ms.

[0127] In the fourth example, PDCP SDUs or PDCP PDUs to be routed to both the primary RLC entity 130 and the split secondary RLC entity 132 comprise packet#1 (RT=12ms) and packet#2 (RT=13ms). PDCP SDUs or PDCP PDUs to be routed to the split secondary RLC entity 132 comprise packet#2 (RT=13ms). RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity 132 comprise packet#4

(RT=18ms). UL data associated with the split secondary path comprises packet#2 (RT=13ms) and packet#4 (RT=18ms). The second set of packets associated with the secondary path comprises packet#2 (RT=13ms). The second DSR comprises data volume of the second set of packets, i.e., data volume of packet#2 (RT=13ms).

[0128] Alternatively, in some implementations, one DSR is used for both the primary path and the secondary path. A single threshold is configured for triggering reporting of the DSR. This will be described with reference to Fig. 4.

[0129] Fig. 4 illustrates a signaling diagram illustrating an example process 400 that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The process 400 may be considered as an example implementation of the process 200. The process 400 may involve the UE 104, the first base station 102-1 and the second base station 102-2 in Fig. 1A or 1B. For the purpose of discussion, the process 200 will be described with reference to Fig. 1A, 1B or 1C.

[0130] In the process 400, the first base station 102-1 may act as an MgNB and the second base station 102-2 may act as an SgNB. Alternatively, the first base station 102-1 may act as the SgNB and the second base station 102-2 may act as the MgNB.

[0131] Actions 210, 220 and 230 in the process 400 are similar to those in the process 200. Details of these actions are omitted for brevity.

[0132] The process 400 is different from the process 300 in actions 410 and 420.

[0133] Specifically, the UE 104 transmits 410, to the first base station 102-1, a DSR of the UL split bearer through the primary path. The DSR is associated with both the primary path and the secondary path. In addition, the UE 104 transmits 420, to the second base station 102-2, the DSR of the UL split bearer through the secondary path. In other words, a common DSR is used for both the primary path and the secondary path.

[0134] In some implementations, if the smallest remaining time of UL data associated with both the primary path and the secondary path is less than or equal to a threshold for triggering reporting of the DSR, the UE 104 triggers the reporting of the DSR. In other words, a single threshold is configured for triggering reporting of the DSR.

[0135] In some implementations, the UL data associated with both the primary path and the secondary path may comprise at least one of the following:

- PDCP SDUs or PDCP PDUs to be transmitted; and
- RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity 130 and the split secondary RLC entity 132.

[0136] In some implementations, the UL data associated with both the primary path and the secondary path may comprise a third set of packets. The DSR may comprise data volume of the third set of packets, and remaining time of the third set of packets is less than or equal to the threshold for triggering reporting of the DSR.

[0137] Consider a fifth example. In the fifth example, a value of a PDCP discard timer is equal to 50ms. The threshold for triggering reporting of the DSR is equal to 15ms.

[0138] In the fifth example, PDCP SDUs or PDCP PDUs to be transmitted comprise packet#1 (RT=12ms) and packet#2 (RT=13ms). RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity 130 comprise packet#3 (RT=20ms). RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity 132 comprise packet#4 (RT=18ms). UL data associated with both the primary path and the secondary path comprises packet#1 (RT=12ms), packet#2 (RT=13ms), packet#3 (RT=20ms) and packet#4 (RT=18ms). The third set of packets associated with both the primary path and the secondary path comprises packet#1 (RT=12ms) and packet#2 (RT=13ms). The DSR comprises data volume of the third set of packets, i.e., data volume of packet#1 (RT=12ms) and packet#2 (RT=13ms).

[0139] In some implementations, the third set of packets may comprise a first subset of packets in the primary RLC entity 130, a second subset of packets in the split secondary RLC entity 132 and a third subset of packets in a PDCP entity 120.

[0140] Still consider the fifth example. In the fifth example, the first subset of packets in the primary RLC entity 130 comprise packet#3 (RT=20ms), the second subset of packets in the split secondary RLC entity 132 comprises packet#4 (RT=18ms), and the third subset of packets in a PDCP entity 120 comprises packet#1 (RT=12ms) and packet#2 (RT=13ms).

[0141] In some implementations, in order to determine the data volume to be included in the DSR at the MAC entity 140 and the MAC entity 142, the primary RLC entity 130 may provide first data volume of the first subset of packets to the MAC entity 142 associated with the split secondary RLC entity 132. The split secondary RLC entity 132

may provide second data volume of the second subset of packets to the MAC entity 140 associated with the primary RLC entity 130. The PDCP entity 120 may provide third data volume of the third subset of packets to the MAC entity 140 and the MAC entity 142, respectively.

[0142] Alternatively, in some implementations, in order to determine the data volume to be included in the DSR at the MAC entity 140 and the MAC entity 142, the MAC entity 140 may provide first data volume of the first subset of packets to the MAC entity 142. The MAC entity 142 may provide second data volume of the second subset of packets from to the MAC entity 140. The PDCP entity 120 may provide third data volume of the third subset of packets to the MAC entity 140 and the MAC entity 142, respectively.

[0143] In some implementations, the UL split is only for particular PDU sets (e.g., PDU set with less importance or with less important PDU Set Importance (PSI)). When the UL split is triggered, the UE 104 only transmits the PDU sets with particular importance via the secondary path. This will be described with reference to Fig. 5.

[0144] Fig. 5 illustrates a signaling diagram illustrating an example process 500 that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The process 500 may be considered as an example implementation of the process 200. The process 500 may involve the UE 104, the first base station 102-1 and the second base station 102-2 in Fig. 1A or 1B. For the purpose of discussion, the process 200 will be described with reference to Fig. 1A, 1B or 1C.

[0145] As shown in Fig. 5, the UE 104 receives 510 a configuration of DRB from the first base station 102-1. Alternatively, the UE 104 may receive the configuration of DRB from the second base station 102-2. The configuration of DRB may indicate that the DRB is configured as a UL split DRB in NR-DC.

[0146] In the process 500, the first base station 102-1 may act as an MgNB and the second base station 102-2 may act as an SgNB. Alternatively, the first base station 102-1 may act as the SgNB and the second base station 102-2 may act as the MgNB.

[0147] The UE 104 receives 515, from the first base station 102-1, an indication indicating that the secondary path is used for at least one PDU Set with at least one value of PSI. Alternatively, the UE 104 may receive the indication from the second base station 102-2.

[0148] In some implementations, the first base station 102-1 or the second base station 102-2 may indicate a primary path and a secondary path of the UL split DRB. Information about the primary path may comprise information indicating a cell group ID and LCID of the primary RLC entity 130. Information about the secondary path may indicate the LCID of the split secondary RLC entity 132, and this RLC entity belongs to a cell group that is different from the cell group for the primary path.

[0149] The UE 104 receives 520, from the first base station 102-1, at least one UL split threshold associated with delay status for a UL split bearer. Alternatively, the UE 104 may receive, from the second base station 102-2, at least one UL split threshold associated with delay status for a UL split bearer. The action 520 in the process 500 is similar to the action 220 in the process 200, 300 and 400. Details of this action is omitted for brevity.

[0150] In turn, the UE 104 triggers 530 UL split for the at least one PDU Set based on the at least one UL split threshold. In other words, based on the at least one UL split threshold, the UE 104 uses the secondary path for UL data transmission of the at least one PDU Set with the at least one value of PSI and the primary path for UL data transmission of all PDU Sets except the at least one PDU set with the at least one value of PSI.

[0151] For example, the at least one PDU set with the at least one value of PSI comprise a first PDU set with a first value of PSI and a second PDU set with a second value of PSI. If the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time, the PDCP entity 120 submits a PDCP PDU in the first PDU set or the second PDU set to the split secondary RLC entity 132. Otherwise, the PDCP entity 120 submits the PDCP PDU in the first PDU set or the second PDU set to the primary RLC entity 130.

[0152] The UE 104 transmits 540, to the first base station 102-1, a first DSR of the UL split bearer through the primary path. The first DSR is associated with the primary path.

[0153] In some implementations, if the smallest remaining time of UL data associated with the primary path is less than or equal to a first threshold for triggering reporting of the first DSR, the UE 104 triggers the reporting of the first DSR.

[0154] Different from the process 300, in the process 500, the UL data associated with the primary path comprises all PDU Sets except the at least one PDU set with the at least one value of PSI. For example, the UL data associated with the primary path comprises all PDU Sets except the first PDU set and the second PDU set.

[0155] The UE 104 transmits 550, to the second base station 102-2, a second DSR of the UL split bearer through the secondary path. The second DSR is associated with the secondary path.

[0156] In some implementations, if the smallest remaining time of UL data associated with the secondary path is less than or equal to a second threshold for triggering reporting of the second DSR, the UE 104 triggers the reporting of the second DSR. The second threshold for triggering reporting of the second DSR is independent or separate from the first threshold for triggering reporting of the first DSR. A value of the second threshold may be the same as or different from a value of the first threshold.

[0157] Different from the process 300, in the process 500, the UL data associated with the secondary path comprises the at least one PDU set with the at least one value of PSI. For example, the UL data associated with the secondary path comprises the first PDU set and the second PDU set.

[0158] Some implementations which have been described with reference to Figs. 2 and 3 are also applicable to the process 500. Details of these implementations are omitted for brevity.

[0159] Fig. 6 illustrates a signaling diagram illustrating an example process 600 that supports PDCP duplication triggered by delay status in accordance with aspects of the present disclosure. The process 600 may involve the UE 104 and the first base station 102-1 or the second base station 102-2 in Fig. 1A or 1B. For the purpose of discussion, the process 600 will be described with reference to Fig. 1A, 1B or 1C.

[0160] As shown in Fig. 6, the UE 104 receives 610, from the first base station 102-1 or the second base station 102-2, at least one threshold for triggering PDCP duplication. PDCP duplication is also referred to as duplication at PDCP.

[0161] In some implementations, the first base station 102-1 may act as an MgNB and the second base station 102-2 may act an SgNB. Alternatively, the first base station 102-1 may act as the SgNB and the second base station 102-2 may act the MgNB.

[0162] In turn, the UE 104 triggers 620 the PDCP duplication based on the at least one threshold.

[0163] In some implementations, when PDCP duplication is configured for a radio bearer, at least one secondary RLC entity 132 is added to the radio bearer to handle the duplicated PDCP PDUs, where the logical channel corresponding to the primary RLC entity 130 is referred to as the primary logical channel, and the logical channel corresponding to the secondary RLC entity 132 is referred to as the secondary logical channel.

[0164] In some implementations, when PDCP duplication is triggered, the UE 104 duplicates a PDCP PDU and uses the primary path associated with the primary RLC entity 130 for UL transmission of the PDCP PDU and the secondary path associated with the split secondary RLC entity 132 for UL transmission of the duplicated PDCP PDU. Therefore, duplication at PDCP consists in submitting the same PDCP PDUs multiple times: once to each activated RLC entity for the radio bearer.

[0165] In some implementations, the at least one threshold for triggering PDCP duplication may comprise a third threshold for remaining time associated with delay status. If the smallest remaining time of UL data is less than or equal to the third threshold for remaining time, the UE 104 may use the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU.

[0166] In some implementations, the at least one threshold for triggering PDCP duplication may comprise a fourth threshold for data volume associated with the delay status. If data volume associated with the delay status is larger than or equal to the fourth threshold for data volume, the UE 104 may use the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU.

[0167] In some implementations, the at least one threshold for triggering PDCP duplication may comprise a third threshold for remaining time associated with delay status and a fourth threshold for data volume associated with the delay status. If remaining time of UL data is less than or equal to the third threshold for remaining time and that data volume associated with the delay status is larger than or equal to the fourth threshold for data volume, the UE 104 may use the primary path for UL transmission of the PDCP PDU and the secondary path for UL transmission of the duplicated PDCP PDU.

[0168] In some implementations, the process 600 may be performed in combination with any of the processes 200 to 500. For example, the actions 610 and 620 may be performed after the actions in any of the processes 200 to 500.

[0169] Some implementations which have been described with reference to Figs. 2 to 5 are also applicable to the process 600. Details of these implementations are omitted for brevity.

[0170] Fig. 7 illustrates an example of a device 700 that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The device 700 may be an example of a base station 102 or a UE 104 as described herein. The device 700 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 700 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 702, a memory 704, a transceiver 708, and, optionally, an I/O controller 708. 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).

[0171] The processor 702, the memory 704, the transceiver 708, 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 702, the memory 704, the transceiver 708, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0172] In some implementations, the processor 702, the memory 704, the transceiver 708, 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 702 and the memory 704 coupled with the processor 702 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704).

[0173] For example, the processor 702 may support wireless communication at the device 700 in accordance with examples as disclosed herein. The processor 702 may be configured to operable to support a means for performing the following: receiving, at a UE from one of a first base station and a second base station, at least one UL split threshold associated with delay status for a UL split bearer; and based on the at least one UL split threshold, using both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

[0174] The processor 702 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 702 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 704) to cause the device 700 to perform various functions of the present disclosure.

[0175] The memory 704 may include random access memory (RAM) and read-only memory (ROM). The memory 704 may store computer-readable, computer-executable code including instructions that, when executed by the processor 702 cause the device 700 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 702 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 704 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.

[0176] The I/O controller 708 may manage input and output signals for the device 700. The I/O controller 708 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 708 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 708 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 708 may be implemented as part of a processor, such as the processor 708. In some implementations, a user may interact with the device 700 via the I/O controller 708 or via hardware components controlled by the I/O controller 708.

[0177] In some implementations, the device 700 may include a single antenna 710. However, in some other implementations, the device 700 may have more than one antenna 710 (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 708 may communicate bi-directionally, via the one or more antennas 710, wired, or wireless links as described herein. For example, the transceiver 708 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 708 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 710 for transmission, and to demodulate packets received from the one or more antennas 710. The transceiver 708 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0178] 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 710 for transmitting the amplified signal into the air or wireless medium.

[0179] 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 710 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.

[0180] Fig. 8 illustrates an example of a processor 800 that supports UL data split triggered by delay status in accordance with aspects of the present disclosure. The processor 800 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 800 may include a controller 802 configured to perform various operations in accordance with examples as described herein. The processor 800 may optionally include at least one memory 804, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 800 may optionally include one or more arithmetic-logic units (ALUs) 806. 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).

[0181] The processor 800 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 800) 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).

[0182] The controller 802 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 800 to cause the processor 800 to support various operations in accordance with examples as described herein. For example, the controller 802 may operate as a control unit of the processor 800, generating control signals that manage the operation of various components of the processor 800. These control signals include enabling or disabling

functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0183] The controller 802 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 804 and determine subsequent instruction(s) to be executed to cause the processor 800 to support various operations in accordance with examples as described herein. The controller 802 may be configured to track memory address of instructions associated with the memory 804. The controller 802 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 802 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 800 to cause the processor 800 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 802 may be configured to manage flow of data within the processor 800. The controller 802 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 800.

[0184] The memory 804 may include one or more caches (e.g., memory local to or included in the processor 800 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 804 may reside within or on a processor chipset (e.g., local to the processor 800). In some other implementations, the memory 804 may reside external to the processor chipset (e.g., remote to the processor 800).

[0185] The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 800, cause the processor 800 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 802 and/or the processor 800 may be configured to execute computer-readable instructions stored in the memory 804 to cause the processor 800 to perform various functions. For example, the processor 800 and/or the controller 802 may be coupled with or to the memory 804, the processor 800, the controller 802, and the memory 804 may be configured to perform various functions described herein. In some examples, the processor 800 may include multiple processors and the memory 804 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.

[0186] The one or more ALUs 806 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 806 may reside within or on a processor chipset (e.g., the processor 800). In some other implementations, the one or more ALUs 806 may reside external to the processor chipset (e.g., the processor 800). One or more ALUs 806 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 806 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 806 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 806 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 806 to handle conditional operations, comparisons, and bitwise operations.

[0187] The processor 800 may support wireless communication in accordance with examples as disclosed herein. The processor 800 may be configured to operable to support a means for performing the following: receiving, at a UE from one of a first base station and a second base station, at least one UL split threshold associated with delay status for a UL split bearer; and based on the at least one UL split threshold, using both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

[0188] Fig. 9 illustrates a flowchart of a method 900 that supports UL data split triggered by delay status 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 operations of the method 900 may be performed by a UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0189] At 910, the method may include receiving, at a UE from one of a first base station and a second base station, at least one UL split threshold associated with delay

status for a UL split bearer. The operations of 910 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 910 may be performed by a device as described with reference to Fig. 1A or 1B.

[0190] At 920, the method may include: based on the at least one UL split threshold, using both a primary path associated with a primary RLC entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer. 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 a device as described with reference to Fig. 1A or 1B.

[0191] It shall be noted that implementations of the present disclosure which have been described with reference to Figs. 2 to 6 are also applicable to the device 900, the processor 800 and the method 900.

[0192] 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.

[0193] 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.

[0194] 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.

[0195] 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.

[0196] As used herein, including in the claims, an article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[0197] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the

disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

1. A user equipment (UE), comprising:
a processor; and
a transceiver coupled to the processor,
wherein the processor is configured to:

receive, via the transceiver from one of a first base station and a second base station, at least one uplink (UL) split threshold associated with delay status for a UL split bearer; and

based on the at least one UL split threshold, use both a primary path associated with a primary radio link control (RLC) entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

2. The UE of claim 1, wherein:

the at least one UL split threshold comprises a first UL split threshold for remaining time associated with delay status; and

the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer:

based on determining that the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

3. The UE of claim 1, wherein:

the at least one UL split threshold comprises a second UL split threshold for data volume associated with the delay status; and

the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by:

based on determining that data volume associated with the delay status is larger than or equal to the second UL split threshold for data volume, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

4. The UE of claim 1, wherein:

the at least one UL split threshold comprises a first UL split threshold for remaining time associated with delay status and a second UL split threshold for data volume associated with the delay status; and

the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by:

based on determining that the smallest remaining time of UL data is less than or equal to the first UL split threshold for remaining time and that data volume associated with the delay status is larger than or equal to the second UL split threshold for data volume, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

5. The UE of claim 3 or 4, wherein the data volume associated with the delay status comprises one of the following:

first data volume of a first set of packets associated with the primary path, wherein remaining time of the first set of packets is less than or equal to a threshold for triggering reporting of a delay status report (DSR),

second data volume of a second set of packets associated with the secondary path, wherein remaining time of the second set of packets is less than or equal to the threshold for triggering the reporting of the DSR, or

a sum of the first data volume and the second data volume.

6. The UE of claim 1, wherein the at least one UL split threshold comprises a third UL split threshold; and

the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by:

based on determining that a total amount of first data volume pending for transmission in a packet data convergence protocol (PDCP) entity of the UE and second data volume pending for initial transmission in the primary RLC entity and the split secondary RLC entity of the UE is equal to or larger than the third UL split threshold, using both the primary path and the secondary path for UL data transmission of the UL split bearer.

7. The UE of claim 1, wherein the processor is further configured to:

transmit, via the transceiver to the first base station and the second base station, a first delay status report (DSR) of the UL split bearer and a second DSR of the UL split bearer through the primary path and the secondary path, respectively, wherein the first DSR is associated with the primary path, and the second DSR is associated with the secondary path.

8. The UE of claim 7, wherein:

the processor is further configured to:

based on determining that the smallest remaining time of UL data associated with the primary path is less than or equal to a first threshold for triggering reporting of the first DSR, trigger the reporting of the first DSR; and

the UL data associated with the primary path comprises at least one of the following:

packet data convergence protocol (PDCP) service data units (SDUs) or PDCP protocol data units (PDUs) to be routed to the primary RLC entity or to be routed to both the primary RLC entity and the split secondary RLC entity; and

RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity.

9. The UE of claim 8, wherein the UL data associated with the primary path comprises a first set of packets associated with the primary path, the first DSR comprises data volume of the first set of packets, and remaining time of the first set of packets is less than or equal to the first threshold for triggering reporting of the first DSR.

10. The UE of claim 7, wherein:

the processor is further configured to:

based on determining that the smallest remaining time of UL data associated with the secondary path is less than or equal to a second threshold for triggering reporting of the second DSR, trigger the reporting of the second DSR; and

the UL data associated with the secondary path comprises at least one of the following:

packet data convergence protocol (PDCP) service data units (SDUs) or PDCP protocol data units (PDUs) to be routed to the split secondary RLC entity or to be routed to both the primary RLC entity and the split secondary RLC entity; and

RLC SDUs or RLC PDUs to be transmitted in the split secondary RLC entity.

11. The UE of claim 1, wherein the processor is further configured to:

transmit, via the transceiver to the first base station and the second base station, a delay status report (DSR) of the UL split bearer through the primary path and the secondary path, respectively, wherein the DSR is associated with both the primary path and the secondary path.

12. The UE of claim 11, wherein:

the processor is further configured to:

based on determining that smallest remaining time of UL data associated with both the primary path and the secondary path is less than or equal to a threshold for triggering reporting of the DSR, trigger the reporting of the DSR; and

the UL data associated with both the primary path and the secondary path comprises at least one of the following:

packet data convergence protocol (PDCP) service data units (SDUs) or PDCP protocol data units (PDUs) to be transmitted; and

RLC SDUs or RLC PDUs to be transmitted in the primary RLC entity and the split secondary RLC entity.

13. The UE of claim 12, wherein the UL data associated with both the primary path and the secondary path comprises a third set of packets associated with both the primary path and the secondary path, the DSR comprises data volume of the third set of packets, and remaining time of the third set of packets is less than or equal to the threshold for triggering reporting of the DSR.

14. The UE of claim 13, wherein the third set of packets comprises a first subset of packets in the primary RLC entity, a second subset of packets in the split secondary RLC entity and a third subset of packets in a PDCP entity of the UE.

15. The UE of claim 14, wherein the processor is further configured to:

provide first data volume of the first subset of packets from the primary RLC entity to a second media access control (MAC) entity of the UE associated with the split secondary RLC entity;

provide second data volume of the second subset of packets from the split secondary RLC entity to a first MAC entity of the UE associated with the primary RLC entity; and

provide third data volume of the third subset of packets from the PDCP entity to the first MAC entity and the second MAC entity, respectively.

16. The UE of claim 14, wherein the processor is further configured to:

provide first data volume of the first subset of packets from a first media access control (MAC) entity of the UE associated with the primary RLC entity to a second MAC entity of the UE associated with the split secondary RLC entity;

provide second data volume of the second subset of packets from the second MAC entity to the first MAC entity; and

provide third data volume of the third subset of packets from the PDCP entity to the first MAC entity and the second MAC entity, respectively.

17. The UE of claim 1, wherein:

the processor is further configured to:

receive, via the transceiver from one of the first base station and the second base station, an indication indicating that the secondary path is used for at least one protocol data unit (PDU) Set with at least one value of PDU Set Importance (PSI); and

the processor is configured to use both the primary path and the secondary path for UL data transmission of the UL split bearer by:

using the secondary path for UL data transmission of the at least one PDU Set with the at least one value of PSI based on the indication.

18. The UE of claim 17, wherein the processor is further configured to:

transmit, via the transceiver to the first base station and the second base station, a first delay status report (DSR) of the UL split bearer and a second DSR of the UL split bearer through the primary path and the secondary path, respectively, wherein the first DSR is associated with the primary path, and the second DSR is associated with the secondary path.

19. A processor for wireless communication, comprising:
at least one memory; and
a controller coupled with the at least one memory and configured to cause the controller to:
receive, from one of a first base station and a second base station, at least one uplink (UL) split threshold associated with delay status for a UL split bearer; and
based on the at least one UL split threshold, use both a primary path associated with a primary radio link control (RLC) entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.

20. A method for wireless communication, comprising:
receiving, at a user equipment (UE) from one of a first base station and a second base station, at least one uplink (UL) split threshold associated with delay status for a UL split bearer; and
based on the at least one UL split threshold, using both a primary path associated with a primary radio link control (RLC) entity of the UE and a secondary path associated with a split secondary RLC entity of the UE for UL data transmission of the UL split bearer.