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PDCP ENHANCEMENTS FOR MULTI-MODAL QOS FLOWS

Abstract

Apparatus, methods, and computer program products for wireless communication are provided. An example method may include receiving, from a network entity, a plurality of coupled SDUs and starting a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. The example method may further include upon arrival of each subsequent SDU of the plurality of coupled SDUs, starting a respective PDCP discard timer associated with the subsequent SDU. The example method may further include discarding the plurality of coupled SDUs or a plurality of PDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION(S) [0001] This application claims the benefit of and priority to U.S. Provisional Application Ser. No. 63/554,114, entitled “PDCP ENHANCEMENTS FOR MULTI-MODAL QOS FLOWS” and filed on Feb. 15, 2024, which is expressly incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to communication systems, and more particularly, to wireless communication systems with multi-modal quality of service (QoS) flows.

INTRODUCTION

[0003] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0004] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability (e.g., with Internet of Things (IoT)), and other requirements. 5G NR includes services associated with enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable low latency communications (URLLC). Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

BRIEF SUMMARY

[0005] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects. This summary neither identifies key or critical elements of all aspects nor delineates the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0006] In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus at a user equipment (UE) are provided. The apparatus may include at least one memory and at least one processor coupled to the at least one memory. Based at least in part on information stored in the at least one memory, the at least one processor is configured to receive, from a network entity, a plurality of coupled service data units (SDUs). Based at least in part on information stored in the at least one memory, the at least one processor is configured to start a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. Based at least in part on information stored in the at least one memory, the at least one processor is configured to upon arrival of each subsequent SDU of the plurality of coupled SDUs, start a

respective PDCP discard timer associated with the subsequent SDU. Based at least in part on information stored in the at least one memory, the at least one processor is configured to discard the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU.
[0007] To the accomplishment of the foregoing and related ends, the one or more aspects include the features hereinafter fully described and particularly pointed out in the claims. The following description and the drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0008] FIG. **1** is a diagram illustrating an example of a wireless communications system and an access network.
[0009] FIG. **2**A is a diagram illustrating an example of a first frame, in accordance with various aspects of the present disclosure.
[0010] FIG. **2**B is a diagram illustrating an example of downlink (DL) channels within a subframe, in accordance with various aspects of the present disclosure.
[0011] FIG. **2**C is a diagram illustrating an example of a second frame, in accordance with various aspects of the present disclosure.
[0012] FIG. **2**D is a diagram illustrating an example of uplink (UL) channels within a subframe, in accordance with various aspects of the present disclosure.
[0013] FIG. **3** is a diagram illustrating an example of a base station and user equipment (UE) in an access network.
[0014] FIG. **4**A illustrates an example of extended reality (XR) traffic for wireless communication, in accordance with various aspects of the present disclosure.
[0015] FIG. **4**B illustrates an example of a UE exchanging XR traffic with an XR service or cloud gaming service, in accordance with various aspects of the present disclosure.
[0016] FIG. **4**C illustrates an example of multiple UEs exchanging multi-modal XR traffic with an XR service or cloud gaming service, in accordance with various aspects of the present disclosure.
[0017] FIG. **5** is a diagram illustrating an example timeline for multi-modality discard and delivery timeline, in accordance with various aspects of the present disclosure.
[0018] FIG. **6** is a diagram illustrating another example timeline for multi-modality discard and delivery timeline, in accordance with various aspects of the present disclosure.
[0019] FIG. **7** is a diagram illustrating example communications between a network entity and a UE, in accordance with various aspects of the present disclosure.
[0020] FIG. **8** is a flowchart of a method of wireless communication, in accordance with various aspects of the present disclosure.
[0021] FIG. **9** is a diagram illustrating an example of a hardware implementation for an example apparatus and/or network entity, in accordance with various aspects of the present disclosure.
DETAILED DESCRIPTION
[0022] The detailed description set forth below in connection with the drawings describes various configurations and does not represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, these concepts may be practiced without these specific details. In some instances, well known structures and components are shown

in block diagram form in order to avoid obscuring such concepts.

[0023] In some wireless communication systems, different data radio bearers (DRBs) and associated quality of service (QOS) flows may be handled independently. However, for multi-modality, different flows may be coupled flows that have inter-dependent delivery deadline(s) and may be synchronized. To facilitate such coupled flows that have inter-dependent delivery deadline(s), joint handling of flows with inter-dependent delivery deadlines may be used. To facilitate such joint handling, coupled flows and coupled service data units (SDUs) may be associated with a same multi-modal service identifier (ID) (MMSI). Aspects provided herein provide enhancements for PDCP discard procedure for multi-modal traffic to improve efficiency of processing multi-modal traffic.

[0024] Several aspects of telecommunication systems are presented with reference to various apparatus and methods. These apparatus and methods are described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0025] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors. When multiple processors are implemented, the multiple processors may perform the functions individually or in combination. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units (CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise, shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, or any combination thereof.

[0026] Accordingly, in one or more example aspects, implementations, and/or use cases, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, such computer-readable media can include a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

[0027] While aspects, implementations, and/or use cases are described in this application by illustration to some examples, additional or different aspects, implementations and/or use cases may come about in many different arrangements and scenarios. Aspects, implementations, and/or use cases described herein may be implemented across many differing platform types, devices, systems, shapes, sizes, and packaging arrangements. For example, aspects, implementations, and/or use cases may come about via integrated chip implementations and other non-module-component based devices (e.g., end-user devices, vehicles, communication devices, computing devices, industrial equipment, retail/purchasing devices, medical devices, artificial intelligence (AI)-enabled devices, etc.). While some examples may or may not be specifically directed to use cases or applications, a wide assortment of applicability of described examples may occur. Aspects, implementations, and/or use cases may range a spectrum from chip-level or modular components to non-modular, non-chip-level implementations and further to aggregate, distributed, or original equipment manufacturer (OEM) devices or systems incorporating one or more techniques herein. In some practical settings, devices incorporating described aspects and features may also include additional components and features for implementation and practice of claimed and described aspect. For example, transmission and reception of wireless signals necessarily includes a number of components for analog and digital purposes (e.g., hardware components including antenna, RF-chains, power amplifiers, modulators, buffer, processor(s), interleaver, adders/summers, etc.). Techniques described herein may be practiced in a wide variety of devices, chip-level components, systems, distributed arrangements, aggregated or disaggregated components, end-user devices, etc. of varying sizes, shapes, and constitution.

[0028] Deployment of communication systems, such as 5G NR systems, may be arranged in multiple manners with various components or constituent parts. In a 5G NR system, or network, a network node, a network entity, a mobility element of a network, a radio access network (RAN) node, a core network node, a network element, or a network equipment, such as a base station (BS), or one or more units (or one or more components) performing base station functionality, may be implemented in an aggregated or disaggregated architecture. For example, a BS (such as a Node B (NB), evolved NB (CNB), NR BS, 5G NB, access point (AP), a transmission reception point (TRP), or a cell, etc.) may be implemented as an aggregated base station (also known as a standalone BS or a monolithic BS) or a disaggregated base station.

[0029] An aggregated base station may be configured to utilize a radio protocol stack that is physically or logically integrated within a single RAN node. A disaggregated base station may be configured to utilize a protocol stack that is physically or logically distributed among two or more units (such as one or more central or centralized units (CUs), one or more distributed units (DUs), or one or more radio units (RUs)). In some aspects, a CU may be implemented within a RAN node, and one or more DUs may be co-located with the CU, or alternatively, may be geographically or virtually distributed throughout one or multiple other RAN nodes. The DUs may be implemented to communicate with one or more RUs. Each of the CU, DU and RU can be implemented as virtual units, i.e., a virtual central unit (VCU), a virtual distributed unit (VDU), or a virtual radio unit (VRU).

[0030] Base station operation or network design may consider aggregation characteristics of base station functionality. For example, disaggregated base stations may be utilized in an integrated access backhaul (IAB) network, an open radio access network (O-RAN (such as the network configuration sponsored by the O-RAN Alliance)), or a virtualized radio access network (vRAN, also known as a cloud radio access network (C-RAN)). Disaggregation may include distributing functionality across two or more units at various physical locations, as well as distributing functionality for at least one unit virtually, which can enable flexibility in network design. The various units of the disaggregated base station, or disaggregated RAN architecture, can be configured for wired or wireless communication with at least one other unit.

[0031] FIG. **1** is a diagram **100** illustrating an example of a wireless communications system and an access network. The illustrated wireless communications system includes a disaggregated base station architecture. The disaggregated base station architecture may include one or more CUs **110** that can communicate directly with a core network **120** via a backhaul link, or indirectly with the core network **120** through one or more disaggregated base station units (such as a Near-Real Time (Near-RT) RAN Intelligent Controller (RIC) **125** via an E2 link, or a Non-Real Time (Non-RT) RIC **115** associated with a Service Management and Orchestration (SMO) Framework **105**, or both). A CU **110** may communicate with one or more DUs **130** via respective midhaul links, such as an F1 interface. The DUs **130** may communicate with one or more RUs **140** via respective fronthaul links. The RUs **140** may communicate with respective UEs **104** via one or more radio frequency (RF) access links. In some implementations, the UE **104** may be simultaneously served by multiple RUs **140**.

[0032] Each of the units, i.e., the CUS **110**, the DUs **130**, the RUs **140**, as well as the Near-RT RICs **125**, the Non-RT RICs **115**, and the SMO Framework **105**, may include one or more interfaces or be coupled to one or more interfaces configured to receive or to transmit signals, data, or information (collectively, signals) via a wired or wireless transmission medium. Each of the units, or an associated processor or controller providing instructions to the communication interfaces of the units, can be configured to communicate with one or more of the other units via the transmission medium. For example, the units can include a wired interface configured to receive or to transmit signals over a wired transmission medium to one or more of the other units.

[0033] Additionally, the units can include a wireless interface, which may include a receiver, a transmitter, or a transceiver (such as an RF transceiver), configured to receive or to transmit signals, or both, over a wireless transmission medium to one or more of the other units.

[0034] In some aspects, the CU **110** may host one or more higher layer control functions. Such control functions can include radio resource control (RRC), packet data convergence protocol (PDCP), service data adaptation protocol (SDAP), or the like. Each control function can be implemented with an interface configured to communicate signals with other control functions hosted by the CU **110**. The CU **110** may be configured to handle user plane functionality (i.e., Central Unit-User Plane (CU-UP)), control plane functionality (i.e., Central Unit-Control Plane (CU-CP)), or a combination thereof. In some implementations, the CU **110** can be logically split into one or more CU-UP units and one or more CU-CP units. The CU-UP unit can communicate bidirectionally with the CU-CP unit via an interface, such as an E1 interface when implemented in an O-RAN configuration. The CU **110** can be implemented to communicate with the DU **130**, as necessary, for network control and signaling.

[0035] The DU **130** may correspond to a logical unit that includes one or more base station functions to control the operation of one or more RUs **140**. In some aspects, the DU **130** may host one or more of a radio link control (RLC) layer, a medium access control (MAC) layer, and one or more high physical (PHY) layers (such as modules for forward error correction (FEC) encoding and decoding, scrambling, modulation, demodulation, or the like) depending, at least in part, on a functional split, such as those defined by 3GPP. In some aspects, the DU **130** may further host one or more low PHY layers. Each layer (or module) can be implemented with an interface configured to communicate signals with other layers (and modules) hosted by the DU **130**, or with the control functions hosted by the CU **110**.

[0036] Lower-layer functionality can be implemented by one or more RUs **140**. In some deployments, an RU **140**, controlled by a DU **130**, may correspond to a logical node that hosts RF processing functions, or low-PHY layer functions (such as performing fast Fourier transform (FFT), inverse FFT (IFFT), digital beamforming, physical random access channel (PRACH) extraction and filtering, or the like), or both, based at least in part on the functional split, such as a lower layer functional split. In such an architecture, the RU(s) **140** can be implemented to handle over the air (OTA) communication with one or more UEs **104**. In some implementations, real-time and non-real-time aspects of control and user plane communication with the RU(s) **140** can be controlled by the corresponding DU **130**. In some scenarios, this configuration can enable the DU(s) **130** and the CU **110** to be implemented in a cloud-based RAN architecture, such as a vRAN architecture.

[0037] The SMO Framework **105** may be configured to support RAN deployment and provisioning of non-virtualized and virtualized network elements. For non-virtualized network elements, the SMO Framework **105** may be configured to support the deployment of dedicated physical resources for RAN coverage requirements that may be managed via an operations and maintenance interface (such as an O1 interface). For virtualized network elements, the SMO Framework **105** may be configured to interact with a cloud computing platform (such as an open cloud (O-Cloud) **190**) to perform network element life cycle management (such as to instantiate virtualized network elements) via a cloud computing platform interface (such as an O2 interface). Such virtualized network elements can include, but are not limited to, CUs **110**, DUs **130**, RUs **140** and Near-RT RICs **125**. In some implementations, the SMO Framework **105** can communicate with a hardware aspect of a 4G RAN, such as an open eNB (O-eNB) **111**, via an O1 interface. Additionally, in some implementations, the SMO Framework **105** can communicate directly with one or more RUs **140** via an O1 interface. The SMO Framework **105** also may include a Non-RT RIC **115** configured to support functionality of the SMO Framework **105**.

[0038] The Non-RT RIC **115** may be configured to include a logical function that enables non-real-time control and optimization of RAN elements and resources, artificial intelligence (AI)/machine learning (ML) (AI/ML) workflows including model training and updates, or policy-based guidance of applications/features in the Near-RT RIC **125**. The Non-RT RIC **115** may be coupled to or communicate with (such as via an A1 interface) the Near-RT RIC **125**. The Near-RT RIC **125** may be configured to include a logical function that enables near-real-time control and optimization of RAN elements and resources via data collection and actions over an interface (such as via an E2 interface) connecting one or more CUs **110**, one or more DUs **130**, or both, as well as an O-eNB, with the Near-RT RIC **125**.

[0039] In some implementations, to generate AI/ML models to be deployed in the Near-RT RIC **125**, the Non-RT RIC **115** may receive parameters or external enrichment information from external servers. Such information may be utilized by the Near-RT RIC **125** and may be received at the SMO Framework **105** or the Non-RT RIC **115** from non-network data sources or from network functions. In some examples, the Non-RT RIC **115** or the Near-RT RIC **125** may be configured to tune RAN behavior or performance. For example, the Non-RT RIC **115** may monitor long-term trends and patterns for performance and employ AI/ML models to perform corrective actions through the SMO Framework **105** (such as reconfiguration via **01**) or via creation of RAN management policies (such as A1 policies).

[0040] At least one of the CU **110**, the DU **130**, and the RU **140** may be referred to as a base station **102**. Accordingly, a base station **102** may include one or more of the CU **110**, the DU **130**, and the RU **140** (each component indicated with dotted lines to signify that each component may or may not be included in the base station **102**). The base station **102** provides an access point to the core network **120** for a UE **104**. The base station **102** may include macrocells (high power cellular base station) and/or small cells (low power cellular base station). The small cells include femtocells, picocells, and microcells. A network that includes both small cell and macrocells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links between the RUs **140** and the UEs **104** may include uplink (UL) (also referred to as reverse link) transmissions from a UE **104** to an RU **140** and/or downlink (DL) (also referred to as forward link) transmissions from an RU **140** to a UE **104**. The communication links may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more carriers. The base station **102**/UEs **104** may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 100, 400, etc. MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or fewer carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

[0041] Certain UEs **104** may communicate with each other using device-to-device (D2D) communication link **158**. The D2D communication link **158** may use the DL/UL wireless wide area network (WWAN) spectrum. The D2D communication link **158** may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, Bluetooth™ (Bluetooth is a trademark of the Bluetooth Special Interest Group (SIG)), Wi-Fi™ (Wi-Fi is a trademark of the Wi-Fi Alliance) based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard, LTE, or NR.

[0042] The wireless communications system may further include a Wi-Fi AP **150** in communication with UEs **104** (also referred to as Wi-Fi stations (STAs)) via communication link **154**, e.g., in a 5 GHz unlicensed frequency spectrum or the like. When communicating in an unlicensed frequency spectrum, the UEs **104**/AP **150** may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.

[0043] The electromagnetic spectrum is often subdivided, based on frequency/wavelength, into various classes, bands, channels, etc. In 5G NR, two initial operating bands have been identified as frequency range designations FR1 (410 MHZ-7.125 GHZ) and FR2 (24.25 GHz-52.6 GHz). Although a portion of FR1 is greater than 6 GHz, FR1 is often referred to (interchangeably) as a “sub-6 GHz” band in various documents and articles. A similar nomenclature issue sometimes occurs with regard to FR2, which is often referred to (interchangeably) as a “millimeter wave” band in documents and articles, despite being different from the extremely high frequency (EHF) band (30 GHz-300 GHz) which is identified by the International Telecommunications Union (ITU) as a “millimeter wave” band.

[0044] The frequencies between FR1 and FR2 are often referred to as mid-band frequencies. Recent 5G NR studies have identified an operating band for these mid-band frequencies as frequency range designation FR3 (7.125 GHZ-24.25 GHZ). Frequency bands falling within FR3 may inherit FR1 characteristics and/or FR2 characteristics, and thus may effectively extend features of FR1 and/or FR2 into mid-band frequencies. In addition, higher frequency bands are currently being explored to extend 5G NR operation beyond 52.6 GHz. For example, three higher operating bands have been identified as frequency range designations FR2-2 (52.6 GHZ-71 GHZ), FR4 (71 GHz-114.25 GHZ), and FR5 (114.25 GHZ-300 GHz). Each of these higher frequency bands falls within the EHF band.

[0045] With the above aspects in mind, unless specifically stated otherwise, the term “sub-6 GHz” or the like if used herein may broadly represent frequencies that may be less than 6 GHz, may be within FR1, or may include mid-band frequencies. Further, unless specifically stated otherwise, the term “millimeter wave” or the like if used herein may broadly represent frequencies that may include mid-band frequencies, may be within FR2, FR4, FR2-2, and/or FR5, or may be within the EHF band.

[0046] The base station **102** and the UE **104** may each include a plurality of antennas, such as antenna elements, antenna panels, and/or antenna arrays to facilitate beamforming. The base station **102** may transmit a beamformed signal **182** to the UE **104** in one or more transmit directions. The UE **104** may receive the beamformed signal from the base station **102** in one or more receive directions. The UE **104** may also transmit a beamformed signal **184** to the base station **102** in one or more transmit directions. The base station **102** may receive the beamformed signal from the UE **104** in one or more receive directions. The base station **102**/UE **104** may perform beam training to determine the best receive and transmit directions for each of the base station **102**/UE **104**. The transmit and receive directions for the base station **102** may or may not be the same. The transmit and receive directions for the UE **104** may or may not be the same.

[0047] The base station **102** may include and/or be referred to as a gNB, Node B, eNB, an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), a TRP, network node, network entity, network equipment, or some other suitable terminology. The base station **102** can be implemented as an integrated access and backhaul (IAB) node, a relay node, a sidelink node, an aggregated (monolithic) base station with a baseband unit (BBU) (including a CU and a DU) and an RU, or as a disaggregated base station including one or more of a CU, a DU, and/or an RU. The set of base stations, which may include disaggregated base stations and/or aggregated base stations, may be referred to as next generation (NG) RAN (NG-RAN).

[0048] The core network **120** may include an Access and Mobility Management Function (AMF) **161**, a Session Management Function (SMF) **162**, a User Plane Function (UPF) **163**, a Unified Data Management (UDM) **164**, one or more location servers **168**, and other functional entities. The AMF **161** is the control node that processes the signaling between the UEs **104** and the core network **120**. The AMF **161** supports registration management, connection management, mobility management, and other functions. The SMF **162** supports session management and other functions. The UPF **163** supports packet routing, packet forwarding, and other functions. The UDM **164** supports the generation of authentication and key agreement (AKA) credentials, user identification handling, access authorization, and subscription management. The one or more location servers **168** are illustrated as including a Gateway Mobile Location Center (GMLC) **165** and a Location Management Function (LMF) **166**. However, generally, the one or more location servers **168** may include one or more location/positioning servers, which may include one or more of the GMLC **165**, the LMF **166**, a position determination entity (PDE), a serving mobile location center (SMLC), a mobile positioning center (MPC), or the like. The GMLC **165** and the LMF **166** support UE location services. The GMLC **165** provides an interface for clients/applications (e.g., emergency services) for accessing UE positioning information. The LMF **166** receives measurements and assistance information from the NG-RAN and the UE **104** via the AMF **161** to compute the position of the UE **104**. The NG-RAN may utilize one or more positioning methods in order to determine the position of the UE **104**. Positioning the UE **104** may involve signal measurements, a position estimate, and an optional velocity computation based on the measurements. The signal measurements may be made by the UE **104** and/or the base station **102** serving the UE **104**. The signals measured may be based on one or more of a satellite positioning system (SPS) **170** (e.g., one or more of a Global Navigation Satellite System (GNSS), global position system (GPS), non-terrestrial network (NTN), or other satellite position/location system), LTE signals, wireless local area network (WLAN) signals, Bluetooth signals, a terrestrial beacon system (TBS), sensor-based information (e.g., barometric pressure sensor, motion sensor), NR enhanced cell ID (NR E-CID) methods, NR signals (e.g., multi-round trip time (Multi-RTT), DL angle-of-departure (DL-AoD), DL time difference of arrival (DL-TDOA), UL time difference of arrival (UL-TDOA), and UL angle-of-arrival (UL-AoA) positioning), and/or other systems/signals/sensors.

[0049] Examples of UEs **104** include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a large or small kitchen appliance, a healthcare device, an implant, a sensor/actuator, a display, or any other similar functioning device. Some of the UEs **104** may be referred to as IoT devices (e.g., parking meter, gas pump, toaster, vehicles, heart monitor, etc.). The UE **104** may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology. In some scenarios, the term UE may also apply to one or more companion devices such as in a device constellation arrangement. One or more of these devices may collectively access the network and/or individually access the network.

[0050] Referring again to FIG. **1**, in some aspects, the UE **104** may include a multi-modal component **198**. In some aspects, the multi-modal component **198** may be configured to receive, from a network entity, a plurality of coupled service data units (SDUs). In some aspects, the multi-modal component **198** may be further configured to start a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. In some aspects, the multi-modal component **198** may be further configured to upon arrival of each subsequent SDU of the plurality of coupled SDUs, start a respective PDCP discard timer associated with the subsequent SDU. In some aspects, the multi-modal component **198** may be further configured to discard the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU.

[0051] Although the following description may be focused on 5G NR, the concepts described herein may be applicable to other similar areas, such as LTE, LTE-A, CDMA, GSM, and other wireless technologies.

[0052] As described herein, a node (which may be referred to as a node, a network node, a network entity, or a wireless node) may include, be, or be included in (e.g., be a component of) a base station (e.g., any base station described herein), a UE (e.g., any UE described herein), a network controller, an apparatus, a device, a computing system, an integrated access and backhauling (IAB) node, a distributed unit (DU), a central unit (CU), a remote/radio unit (RU) (which may also be referred to as a remote radio unit (RRU)), and/or another processing entity configured to perform any of the techniques described herein. For example, a network node may be a UE. As another example, a network node may be a base station or network entity. As another example, a first network node may be configured to communicate with a second network node or a third network node. In one aspect of this example, the first network node may be a UE, the second network node may be a base station, and the third network node may be a UE. In another aspect of this example, the first network node may be a UE, the second network node may be a base station, and the third network node may be a base station. In yet other aspects of this example, the first, second, and third network nodes may be different relative to these examples. Similarly, reference to a UE, base station, apparatus, device, computing system, or the like may include disclosure of the UE, base station, apparatus, device, computing system, or the like being a network node. For example, disclosure that a UE is configured to receive information from a base station also discloses that a first network node is configured to receive information from a second network node. Consistent with this disclosure, once a specific example is broadened in accordance with this disclosure (e.g., a UE is configured to receive information from a base station also discloses that a first network node is configured to receive information from a second network node), the broader example of the narrower example may be interpreted in the reverse, but in a broad open-ended way. In the example above where a UE is configured to receive information from a base station also discloses that a first network node is configured to receive information from a second network node, the first network node may refer to a first UE, a first base station, a first apparatus, a first device, a first computing system, a first set of one or more one or more components, a first processing entity, or the like configured to receive the information; and the second network node may refer to a second UE, a second base station, a second apparatus, a second device, a second computing system, a second set of one or more components, a second processing entity, or the like.

[0053] As described herein, communication of information (e.g., any information, signal, or the like) may be described in various aspects using different terminology. Disclosure of one communication term includes disclosure of other communication terms. For example, a first network node may be described as being configured to transmit information to a second network node. In this example and consistent with this disclosure, disclosure that the first network node is configured to transmit information to the second network node includes disclosure that the first network node is configured to provide, send, output, communicate, or transmit information to the second network node. Similarly, in this example and consistent with this disclosure, disclosure that the first network node is configured to transmit information to the second network node includes disclosure that the second network node is configured to receive, obtain, or decode the information that is provided, sent, output, communicated, or transmitted by the first network node.

[0054] FIG. **2**A is a diagram **200** illustrating an example of a first subframe within a 5G NR frame structure. FIG. **2**B is a diagram **230** illustrating an example of DL channels within a 5G NR subframe. FIG. **2**C is a diagram **250** illustrating an example of a second subframe within a 5G NR frame structure. FIG. **2**D is a diagram **280** illustrating an example of UL channels within a 5G NR subframe. The 5G NR frame structure may be frequency division duplexed (FDD) in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for either DL or UL, or may be time division duplexed (TDD) in which for a particular set of subcarriers (carrier system bandwidth), subframes within the set of subcarriers are dedicated for both DL and UL. In the examples provided by FIGS. **2**A, **2**C, the 5G NR frame structure is assumed to be TDD, with subframe 4 being configured with slot format 28 (with mostly DL), where D is DL, U is UL, and F is flexible for use between DL/UL, and subframe 3 being configured with slot format 1 (with all UL). While subframes 3, 4 are shown with slot formats 1, 28, respectively, any particular subframe may be configured with any of the various available slot formats 0-61. Slot formats 0, 1 are all DL, UL, respectively. Other slot formats 2-61 include a mix of DL, UL, and flexible symbols. UEs are configured with the slot format (dynamically through DL control information (DCI), or semi-statically/statically through radio resource control (RRC) signaling) through a received slot format indicator (SFI). Note that the description infra applies also to a 5G NR frame structure that is TDD.

[0055] FIGS. **2**A-**2**D illustrate a frame structure, and the aspects of the present disclosure may be applicable to other wireless communication technologies, which may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized subframes (1 ms). Each subframe may include one or more time slots. Subframes may also include mini-slots, which may include 7, 4, or 2 symbols. Each slot may include 14 or 12 symbols, depending on whether the cyclic prefix (CP) is normal or extended. For normal CP, each slot may include 14 symbols, and for extended CP, each slot may include 12 symbols. The symbols on DL may be CP orthogonal frequency division multiplexing (OFDM) (CP-OFDM) symbols. The symbols on UL may be CP-OFDM symbols (for high throughput scenarios) or discrete Fourier transform (DFT) spread OFDM (DFT-s-OFDM) symbols (for power limited scenarios; limited to a single stream transmission). The number of slots within a subframe is based on the CP and the numerology. The numerology defines the subcarrier spacing (SCS) (see Table 1). The symbol length/duration may scale with 1/SCS.

TABLE-US-00001 TABLE 1 Numerology, SCS, and CP SCS μ Δf = 2.sup.μ .Math. 15[kHz] Cyclic prefix 0 15 Normal 1 30 Normal 2 60 Normal, Extended 3 120 Normal 4 240 Normal 5 480 Normal 6 960 Normal

[0056] For normal CP (14 symbols/slot), different numerologies μ 0 to 4 allow for 1, 2, 4, 8, and 16 slots, respectively, per subframe. For extended CP, the numerology 2 allows for 4 slots per subframe. Accordingly, for normal CP and numerology u, there are 14 symbols/slot and 2.sup.μ slots/subframe. The subcarrier spacing may be equal to 2.sup.μ*15 kHz, where μ is the numerology 0 to 4. As such, the numerology μ=0 has a subcarrier spacing of 15 kHz and the numerology μ=4 has a subcarrier spacing of 240 kHz. The symbol length/duration is inversely related to the subcarrier spacing. FIGS. **2**A-**2**D provide an example of normal CP with 14 symbols per slot and numerology μ=2 with 4 slots per subframe. The slot duration is 0.25 ms, the subcarrier spacing is 60 kHz, and the symbol duration is approximately 16.67 μs. Within a set of frames, there may be one or more different bandwidth parts (BWPs) (see FIG. **2**B) that are frequency division multiplexed. Each BWP may have a particular numerology and CP (normal or extended).

[0057] A resource grid may be used to represent the frame structure. Each time slot includes a resource block (RB) (also referred to as physical RBs (PRBs)) that extends 12 consecutive subcarriers. The resource grid is divided into multiple resource elements (REs). The number of bits carried by each RE depends on the modulation scheme.
[0058] As illustrated in FIG. **2**A, some of the REs carry reference (pilot) signals (RS) for the UE. The RS may include demodulation RS (DM-RS) (indicated as R for one particular configuration, but other DM-RS configurations are possible) and channel state information reference signals (CSI-RS) for channel estimation at the UE. The RS may also include beam measurement RS (BRS), beam refinement RS (BRRS), and phase tracking RS (PT-RS).
[0059] FIG. **2**B illustrates an example of various DL channels within a subframe of a frame. The physical downlink control channel (PDCCH) carries DCI within one or more control channel elements (CCEs) (e.g., 1, 2, 4, 8, or 16 CCEs), each CCE including six RE groups (REGs), each REG including 12 consecutive REs in an OFDM symbol of an RB. A PDCCH within one BWP may be referred to as a control resource set (CORESET). A UE is configured to monitor PDCCH candidates in a PDCCH search space (e.g., common search space, UE-specific search space) during PDCCH monitoring occasions on the CORESET, where the PDCCH candidates have different DCI formats and different aggregation levels. Additional BWPs may be located at greater and/or lower frequencies across the channel bandwidth. A primary synchronization signal (PSS) may be within symbol 2 of particular subframes of a frame. The PSS is used by a UE **104** to determine subframe/symbol timing and a physical layer identity. A secondary synchronization signal (SSS) may be within symbol 4 of particular subframes of a frame. The SSS is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the DM-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSS and SSS to form a synchronization signal (SS)/PBCH block (also referred to as SS block (SSB)). The MIB provides a number of RBs in the system bandwidth and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.
[0060] As illustrated in FIG. **2**C, some of the REs carry DM-RS (indicated as R for one particular configuration, but other DM-RS configurations are possible) for channel estimation at the base station. The UE may transmit DM-RS for the physical uplink control channel (PUCCH) and DM-RS for the physical uplink shared channel (PUSCH). The PUSCH DM-RS may be transmitted in the first one or two symbols of the PUSCH. The PUCCH DM-RS may be transmitted in different configurations depending on whether short or long PUCCHs are transmitted and depending on the particular PUCCH format used. The UE may transmit sounding reference signals (SRS). The SRS may be transmitted in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.
[0061] FIG. **2**D illustrates an example of various UL channels within a subframe of a frame. The PUCCH may be located as indicated in one configuration. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and hybrid automatic repeat request (HARQ) acknowledgment (ACK) (HARQ-ACK) feedback (i.e., one or more HARQ ACK bits indicating one or more ACK and/or negative ACK (NACK)). The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.
[0062] FIG. **3** is a block diagram of a base station **310** in communication with a UE **350** in an access network. In the DL, Internet protocol (IP) packets may be provided to a controller/processor **375**. The controller/processor **375** implements layer 3 and layer 2 functionality. Layer 3 includes a

radio resource control (RRC) layer, and layer 2 includes a service data adaptation protocol (SDAP) layer, a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor **375** provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression/decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0063] The transmit (TX) processor **316** and the receive (RX) processor **370** implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor **316** handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator **374** may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE **350**. Each spatial stream may then be provided to a different antenna **320** via a separate transmitter **318**Tx. Each transmitter **318**Tx may modulate a radio frequency (RF) carrier with a respective spatial stream for transmission.

[0064] At the UE **350**, each receiver **354**Rx receives a signal through its respective antenna **352**. Each receiver **354**Rx recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor **356**. The TX processor **368** and the RX processor **356** implement layer 1 functionality associated with various signal processing functions. The RX processor **356** may perform spatial processing on the information to recover any spatial streams destined for the UE **350**. If multiple spatial streams are destined for the UE **350**, they may be combined by the RX processor **356** into a single OFDM symbol stream. The RX processor **356** then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal includes a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station **310**. These soft decisions may be based on channel estimates computed by the channel estimator **358**. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station **310** on the physical channel. The data and control signals are then provided to the controller/processor **359**, which implements layer 3 and layer 2 functionality.

[0065] The controller/processor **359** can be associated with at least one memory **360** that stores program codes and data. The at least one memory **360** may be referred to as a computer-readable medium. In the UL, the controller/processor **359** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets. The controller/processor **359** is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0066] Similar to the functionality described in connection with the DL transmission by the base station **310**, the controller/processor **359** provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression/decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0067] Channel estimates derived by a channel estimator **358** from a reference signal or feedback transmitted by the base station **310** may be used by the TX processor **368** to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor **368** may be provided to different antenna **352** via separate transmitters **354**Tx. Each transmitter **354**Tx may modulate an RF carrier with a respective spatial stream for transmission.

[0068] The UL transmission is processed at the base station **310** in a manner similar to that described in connection with the receiver function at the UE **350**. Each receiver **318**Rx receives a signal through its respective antenna **320**. Each receiver **318**Rx recovers information modulated onto an RF carrier and provides the information to a RX processor **370**.

[0069] The controller/processor **375** can be associated with at least one memory **376** that stores program codes and data. The at least one memory **376** may be referred to as a computer-readable medium. In the UL, the controller/processor **375** provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets. The controller/processor **375** is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0070] At least one of the TX processor **368**, the RX processor **356**, and the controller/processor **359** may be configured to perform aspects in connection with multi-modal component **198** of FIG. **1**.

[0071] A wireless communication network may support various types of wireless traffic. As an example of one type of traffic, XR traffic may refer to wireless communications for technologies such as virtual reality (VR), mixed reality (MR), and/or augmented reality (AR). VR may refer to technologies in which a user is immersed in a simulated experience that is similar or different from the real world. A user may interact with a VR system through a VR headset or a multi-projected environment that generates realistic images, sounds, and other sensations that simulate a user's physical presence in a virtual environment. MR may refer to technologies in which aspects of a virtual environment and a real environment are mixed. AR may refer to technologies in which objects residing in the real world are enhanced via computer-generated perceptual information, sometimes across multiple sensory modalities, such as visual, auditory, haptic, somatosensory, and/or olfactory. An AR system may incorporate a combination of real and virtual worlds, real-time interaction, and accurate three-dimensional registration of virtual objects and real objects. In an example, an AR system may overlay sensory information (e.g., images) onto a natural environment and/or mask real objects from the natural environment. XR traffic may include video data and/or audio data. XR traffic may be transmitted by a base station and received by a UE or the XR traffic may be transmitted by a UE and received by a base station.

[0072] XR traffic may arrive in periodic traffic bursts ("XR traffic bursts"). An XR traffic burst may vary in a number of packets per burst and/or a size of each pack in the burst. The diagram **400** in FIG. **4**A illustrates a first XR flow **402** that includes a first XR traffic burst **404** and a second XR traffic burst **406**. As illustrated in the diagram **400**, the traffic bursts may include different numbers of packets, e.g., the first XR traffic burst **404** being shown with three packets (represented as rectangles in the diagram **400**) and the second XR traffic burst **406** being shown with two packets. Furthermore, as illustrated in the diagram **400**, the three packets in the first XR traffic burst **404** and the two packets in the second XR traffic burst **406** may vary in size, that is, packets within the first XR traffic burst **404** and the second XR traffic burst **406** may include varying amounts of data.

[0073] XR traffic bursts may arrive at non-integer periods (i.e., in a non-integer cycle). The periods may be different than an integer number of symbols, slots, etc. In an example, for 60 frames per second (FPS) video data, XR traffic bursts may arrive in 1/60=16.67 ms periods. In another example, for 120 FPS video data, XR traffic bursts may arrive in 1/120=8.33 ms periods.

[0074] Arrival times of XR traffic may vary. For example, XR traffic bursts may arrive and be available for transmission at a time that is earlier or later than a time at which a UE (or a base station) expects the XR traffic bursts. The variability of the packet arrival relative to the period (e.g., 16.76 ms period, 8.33 ms period, etc.) may be referred to as "jitter." In an example, jitter for XR traffic may range from −4 ms (earlier than expected arrival) to +4 ms (later than expected arrival). For instance, referring to the first XR flow **402**, a UE may expect a first packet of the first XR traffic burst **404** to arrive at time to, but the first packet of the first XR traffic burst **404** arrives at time t1.

[0075] XR traffic may include multiple flows that arrive at a UE (or a base station) concurrently with one another (or within a threshold period of time). For instance, the diagram **400** includes a second XR flow **408**. The second XR flow **408** may have different characteristics than the first XR flow **402**. For instance, the second XR flow **408** may have XR traffic bursts with different numbers of packets, different sizes of packets, etc. In an example, the first XR flow **402** may include video data and the second XR flow **408** may include audio data for the video data. In another example, the first XR flow **402** may include intra-coded picture frames (I-frames) that include complete images and the second XR flow **408** may include predicted picture frames (P-frames) that include changes from a previous image.

[0076] FIG. **4**B is a diagram **450** illustrating an example of wireless communication between a user equipment (UE) **452**, a base station **454**, and a cloud server **456**. In some aspects, the service provided to the UE **452** may be an XR service or a cloud gaming service, and the associated traffic may be associated with a low latency. As an example, the uplink (UL) packet **460** may include input information such as tracking information or user pose information for the XR service or inputs for the cloud gaming service. In some examples, the UL packet **460** may include data of 100 bytes every 2 ms (at 500 Hz). The cloud server **456** may receive the UL packet **460** and generate the downlink (DL) packet **462** based on the received UL packet **460**. For example, the cloud server **456** may receive the UL packet **460** including the tracking/pose information for the XR service or inputs for the cloud gaming service, and generate the DL packet **462** based on the received UL packet **460** including the tracking/pose information for the XR service or inputs for the cloud gaming service.

[0077] The DL packet **462** may include an encoded data associated with the service provided to the UE. For example, the encoded data may include data of over 100 kilobytes at 45, 60, 75, or 90 frames per second (fps), i.e., every 22, 16, 13, or 11 milliseconds. The XR service or the cloud gaming service may be provided from a cloud server, and the DL packet **462** may include a quasi-periodic encoded video with burst frame every 1/fps seconds or two, possibly staggered, "eye-buffers" (or images) per frame every 1/2*fps seconds. In an example in which the UE is provided with the cloud gaming service, the DL packet **462** may include a quasi-periodic encoded video with burst frame every 1/fps seconds. In an example in which the UE is provided with the XR service, the DL packet **462** may include a quasi-periodic encoded video with separate images, staggered or simultaneously, for each eye per frame every 1/2*fps seconds. In some aspects, the latency observed from the UE **452** may be associated with a round-trip time (RTT) between transmitting the UL packet **460** and receiving the DL packet **462**. That is, the network latency experienced at the UE **452** may be determined based on a RTT between transmitting the UL packet **460** including the tracking/pose information for the XR service or the inputs for the cloud gaming service and receiving the DL packet including the encoded data associated with the service provided to the UE **452**.

[0078] FIG. **4**C is a diagram **475** illustrating a set of multiple UEs (e.g., including UE **474** and UE **476**) associated with different multi-modal flows (e.g., XR traffic A **480** and XR traffic B **482**) of a multi-modal service provided by a server **477** via a base station **472** in accordance with some aspects of the disclosure. Diagram **475** illustrates that each UE may be associated with a different type of data (audio, visual, and/or tactile/haptic, etc.) and/or different data flows. As an example, the UE **474** may correspond to VR glasses, and the UE **476** may correspond to gloves associated with the same VR service as the VR glasses. The VR service may be for an immersive multi-modal VR application. The immersive experience may be based on data from multi-modal flows being received by the UE within a time period that meets a synchronization threshold. While each traffic flow may have different traffic patterns (e.g., periodicity) and/or QoS requirements (e.g., delay budget), the traffic may have inter-dependent delivery deadlines. For example, if a video frame is delivered but its associated audio frame is not delivered within a threshold number of milliseconds, the overall user experience may be impacted. Table 2 illustrates example synchronization thresholds.

TABLE-US-00002 TABLE 2 Example Synchronization thresholds for immersive multi-modal VR application Flow types Synchronization thresholds Audio-Tactile Audio delay: 50 ms Tactile delay 25 ms Visual-Tactile Visual delay: 15 ms Tactile delay: 50 ms Note 1: For each media component, “delay” refers to the case where that media component is delayed compared to the other.

[0079] In an example, a VR service including audio, visual, and/or haptic data and/or traffic may be associated with multiple UEs (e.g., wireless devices such as VR goggles providing audio/visual content, gloves or other wearable devices providing haptic and/or tactile feedback, or other VR/XR devices). The tactile and multi-modal communication services may enable multi-modal interactions, combining ultra-low latency with extremely high availability, reliability, and/or security. An immersive user experience may be based on reception of the multi-modal flows (e.g., multi-modal data and/or traffic) by the UEs within synchronization thresholds. For example, audio data may be delayed by up to 50 ms compared to related tactile/haptic data while tactile/haptic data may be delayed by up to 25 ms compared to related audio data. In some aspects, visual data may be delayed by up to 15 ms compared to related tactile/haptic data while tactile/haptic data may be delayed by up to 50 ms compared to related visual data.

[0080] As used herein, the term “coupled SDUs” may refer to multiple SDUs from different quality of service (QOS) flows or different traffic flows that are defined to be coupled. For example, an XR device may include generate multiple types of traffic flows, such as haptic traffic flow, video traffic flow, or audio traffic flow. Each of the different traffic flows or the different QoS flows may have different traffic patterns (e.g., different periodicity, different data rate, or the like). Each of the different traffic flows or the different QoS flows may also have different QoS requirements (e.g., different delay budget). Despite the differences, each of the different traffic flows or the different QoS flows associated with coupled SDUs may have inter-dependent delivery deadline(s). For example, delivery deadline for a video frame and an associated audio frame may be dependent on each other. If a video frame is delivered but its associated audio frame is not delivered within a defined period of time, the overall user experience may be impacted. Therefore, coupled SDUs may have inter-dependent delivery deadline(s) where delivery deadline of the different traffic flows may be dependent on each other. As used herein, different traffic flows or the different Qos flows associated with inter-dependent delivery deadline(s) may be referred to as "coupled flows."

[0081] In some wireless communication systems, different data radio bearers (DRBs) and associated QoS flows may be handled independently. However, for multi-modality, the different flows may be coupled flows that have inter-dependent delivery deadline(s) and may be synchronized. To facilitate such coupled flows that have inter-dependent delivery deadline(s), joint handling of flows with inter-dependent delivery deadlines may be used. To facilitate such joint handling, coupled flows and coupled SDUs may be associated with a same multi-modal service identifier (ID) (MMSI). Aspects provided herein provide enhancements for PDCP discard procedure for multi-modal traffic to improve efficiency of processing multi-modal traffic.

[0082] As used herein, the term "PDCP discard timer" may refer to a default PDCP discard timer of a DRB (e.g., timers for different DRBs may have different durations) or a congestion specific PDCP discard timer that may be adjusted based on a congestion state at a wireless device. A PDCP discard timer may be denoted by "T.sub.discard," A network may configure a default PDCP discard timer for each DRB. The duration of the default PDCP discard timer may be set to the packet delay budget (PDB) of the QoS flow(s) in the DRB. A UE may start a PDCP discard timer for each PDCP SDU upon its arrival and a UE may discard the SDU or a PDCP PDU associated with the SDU when the associated PDCP discard timer expires. Arrival time of an SDU may be denoted by "A.sub.i." By discarding the SDU or the PDCP PDU associated with the SDU, the UE or the network may no longer spend more resources repeating its transmission (because it may become obsolete to the application), therefore saving resources at the UE, the network, or over the air. A congestion specific PDCP discard timer may be activated or deactivated (e.g., by the network) based on a UE's congestion state. For example, when congestion state is activated, the UE may apply a different (e.g., shorter) PDCP discard timer for SDUs/PDUs with lower importance.

[0083] As used herein, the term "delivery time window" may refer to a delivery time window shared by a plurality of coupled flows, which may share a same MMSI. A delivery time window may be denoted by "L.sub.MM_delivery." For a particular SDU, there may be an expiration time associated with a particular PDCP discard timer for that SDU. The expiration timer of the PDCP discard timer for the i.sup.th SDU may be denoted by "D.sub.i."

[0084] To configure inter-dependency between flows, configuration may be made at the level of QoS flows or at the level of SDUs/PDUs. For QoS flow level configuration, a QoS flow can be configured by RRC whether it is associated with a MMSI. Downlink and uplink of a same QoS flow can be configured with different MMSIs. For example, UL of a QoS flow may be associated with an MMSI but its DL counterpart may be not with the MMSI. Each MMSI may configured by RRC with a duration of common delivery time window L.sub.MM-delivery. The duration of common delivery time window L.sub.MM-delivery may be shared by all QoS flows with the same MMSI. Each DRB may be configured with a default duration for its PDCP discard timer T.sub.discard. The duration of T.sub.discard may be different for different DRBs. For PDU/SDU level configuration, it may be up to UE implementation to identify PDUs from different flows that share the same delivery deadline. The delivery deadline may be set based on L.sub.MM-delivery and the arrival time of the first PDU among such PDUs. The network may provide UE with assistance information that includes a set of real-time transport protocol (RTP) or a set of Internet protocol (IP) header fields for UE to identify which set of PDUs are coupled (i.e. may share the same MMSI and delivery deadline).

[0085] Within QoS flows with the same MMSI, a UE may generate sequence numbers for each group of coupled PDUs that share the same delivery deadline. The generated sequence number may be referred to as multi-modal sequence number denoted by N.sub.MM-SeqNum. Each N.sub.MM-SeqNum may be associated with its own delivery deadline. In some aspects, the sequence number may be transmitted over the air as a field in a header of a PDCP PDU. In some aspects, the sequence number may be not transmitted.

[0086] FIG. **5** is a diagram **500** illustrating an example timeline for multi-modality discard and delivery timeline, in accordance with various aspects of the present disclosure. In some aspects, when a new PDCP SDU arrives (e.g., at A1 **504**), the UE may start the PDCP discard timer for the SDU with a duration based on the default PDCP discard timer of its associated DRB (e.g., equal to T.sub.discard of its associated DRB, T.sub.discard,1 **506** with expiration time D1 **510**). If the SDU is not associated with an existing N.sub.MM-SeqNum, which means that the SDU is a first SDU/PDU among the SDUs/PDUs for a MMSI (and a plurality of coupled flow or SDUs associated with the MMSI), the UE may increment N.sub.MM-SeqNum and set the new value as the N.sub.MM-SeqNum for the SDU. The UE may also start a timer T.sub.MM-delivery (which may be referred to as a common delivery timer, common delivery deadline timer, or delivery timer) with duration equal to T.sub.discard+L.sub.MM-delivery (e.g., T.sub.discard,1+L.sub.MM-delivery **508** as illustrated in FIG. **5**). This first SDU may be identified by the UE as a reference SDU.
[0087] If an SDU is associated with an existing MMSI (e.g., a subsequent SDU), if the SDU's PDCP discard timer has an earlier expiration time than the expiration time of the reference SDU, the UE may identify the SDU with the earlier expiration time than the expiration time of the reference SDU as a new reference SDU and restart the timer T.sub.MM-delivery (which may be referred to as a common delivery timer, common delivery deadline timer, or delivery timer) with duration equal to T.sub.discard+L.sub.MM-delivery, where T.sub.discard is the PDCP discard timer of the new reference SDU. When the timer T.sub.MM-delivery expires, all PDUs that are associated with this N.sub.MM-SeqNum and whose PDCP discard timers are still running may be discarded. In such aspects, changes in congestion state (activated or deactivated) may not affect the discard timer or the delivery timer.
[0088] Referring back to FIG. **5**, when a first SDU in flow 1 **502** arrives at A1 **504**, the UE may start its PDCP discard timer with duration based on a default PDCP discard timer for a DRB associated with the flow 1 **502** (equal to T.sub.discard,1 **506**), which may expire at **510**. Because this is the first SDU in a plurality of coupled SDUs, the UE may also start a timer based on a common delivery deadline (e.g., with duration equal to T.sub.discard,1+L.sub.MM_delivery). When a second SDU in the second flow **522** arrives at **524**, the UE may start its PDCP discard timer with duration based on a default PDCP discard timer for a DRB associated with the flow 2 **522** (equal to T.sub.discard,2 **526**). In some aspects, the two different flows may have different duration configuration for their respective default PDCP discard timer. In some aspects, the two different flows may have a same duration configuration for their respective default PDCP discard timer. If the expiration time D2 **530** (equal to A2+T.sub.discard,2) of the PDCP discard timer for the second SDU is smaller than D1 (equal to A1+T.sub.discard,1), as illustrated in FIG. **5**, the UE may restart the common delivery timer and identify the second SDU as the new reference SDU for the plurality of coupled SDUs. As a result, the new common delivery timer for the plurality of coupled SDUs may be equal to D2+L.sub.MM_delivery **528** after the arrival of the second SDU. In such aspects, the remaining time of a PDU's discard timer is not related to the PDU's actual delivery deadline. Therefore, the remaining time of the discard timer reported in a delay status report (DSR) may not reflect the true time left before its discard. To accurately reflect the remaining time in DSR for PDUs in multi-modal flows, the UE may report a minimum between the remaining time of PDCP discard timer and the remaining time of common delivery timer T.sub.MM_delivery in a DSR transmitted from the UE to the network.
[0089] In some aspects, when the first SDU in a plurality of coupled SDUs arrives, the UE may start a reference timer T.sub.ref and the duration of the reference timer may be equal to a default PDCP discard timer of a DRB associated with the first SDU or a congestion specific PDCP discard timer of a DRB associated with the first SDU. The reference timer may be used for tracking the earliest expiry of PDCP discard timers among all SDUs of the plurality of coupled SDUs. Upon arrival of every SDU from a flow within the associated with the plurality of coupled SDUs, the UE may: (1) if the PDCP discard timer is shorter than the remaining time of the reference timer

T.sub.ref, restart the reference timer T.sub.ref with a new duration equal to the default PDCP discard timer of the SDU or congestion specific PDCP discard timer of the SDU, and for every SDU or PDU associated with the plurality of coupled SDUs, restart its discard timer with a duration equal to a minimum of a remaining time of its default PDCP discard timer or congestion specific PDCP discard timer and the new reference timer plus a duration based on the common delivery window (e.g., min (remaining time of its default PDCP discard timer, the new T.sub.ref+T.sub.MM_delivery); (2) otherwise, start the PDCP discard timer with the duration equal to its default PDCP discard timer or congestion specific PDCP discard timer associated with the SDU's DRB. In such aspects, PDCP discard may be performed for individual SDUs when each SDU's own PDCP discard timer expires. In such aspects, changes in congestion state may affect effective remaining time of SDUs. For example, when congestion is activated or deactivated, the UE may recalculate the duration of a SDU's discard timer, which equals minimum between its congestion-specific PDCP discard timer and remaining time of T.sub.MM-delivery.

[0090] FIG. **6** is a diagram **600** illustrating another example timeline for multi-modality discard and delivery timeline, in accordance with various aspects of the present disclosure. As illustrated in FIG. **6**, when a first SDU in flow 1 **602** arrives at A1 **604**, the UE may start its PDCP discard timer with duration based on a default or congestion specific PDCP discard timer for a DRB associated with the flow 1 **602** (equal to T.sub.discard,1 **606**), which may expire at **610**. Because this is the first SDU in a plurality of coupled SDUs, the UE may also start a reference timer T.sub.ref **608** with the same duration. When a second SDU in the second flow **622** arrives at **624**, the UE may start its PDCP discard timer with duration based on a default or congestion specific PDCP discard timer for a DRB associated with the flow 2 **622** (equal to T.sub.discard,2 **626**). Because the expiration time D2 **630** (equal to A2+T.sub.discard,2) of the PDCP discard timer for the second SDU is smaller than D1 (equal to A1+T.sub.discard,1), as illustrated in FIG. **6**, the UE may restart the reference timer with a new duration **628** equal to T.sub.discard,2 **626** because the second SDU has an earlier expiration time D2 **630**. The UE may then update the PDCP discard timers of all PDUs which current expiry time may be beyond the time window **632** of (D2, D2+L.sub.MM_delivery), (e.g., set them to T.sub.MM_delivery plus new value of T.sub.ref). In such aspects, because the duration of a PDU's PDCP discard timer is based on the common delivery deadline, the remaining time of its discard timer reported in a DSR may reflect the true time left before a PDU is discarded.

[0091] FIG. **7** is a diagram **700** illustrating example communications between a network entity **704** and a UE **702**, in accordance with various aspects of the present disclosure.

[0092] The network entity **704** may transmit a configuration **705** for a plurality of coupled QoS flows to the UE **702**. For example, the configuration **705** may be associated with an XR application. The configuration **705** may be made at the level of QoS flows or at the level of SDUs/PDUs as described herein and may be based on RRC. The network entity **704** may transmit a first SDU **706** of a plurality of coupled SDUs (which may be included in one QoS flow of a plurality of coupled flows) to the UE **702**. Upon arrival of the first SDU **706**, at **708**, the UE may start a timer associated with the plurality of coupled SDUs. In some aspects, the timer may be a reference timer (e.g., as described in connection with FIG. **6**). In some aspects, the timer may be a common delivery timer (e.g., as described in connection with FIG. **5**). In some aspects, the UE **702** may generate, at **709**, an MMSI associated with the plurality of coupled SDUs upon reception of the first SDU (e.g., which may be identified based on identifying the first SDU as not associated with an existing MMSI). The network entity **704** may transmit subsequent SDU(s) **706** of the plurality of coupled SDUs to the UE **702**. At **712**, upon arrival of each subsequent SDU of the plurality of coupled SDUs, the UE **702** may start a respective PDCP discard timer associated with the subsequent SDU. In some aspects, the respective PDCP discard timer associated with the subsequent SDU may be based on a default PDCP discard timer associated with a respective DRB associated with the subsequent SDU. In some aspects, the respective PDCP discard timer associated with the subsequent SDU may be based on a congestion specific PDCP discard timer associated with a respective DRB associated with the subsequent SDU.

[0093] In some aspects, for each subsequent SDU, if the SDU's PDCP discard timer has an earlier expiration time than the common delivery timer based on the reference SDU (e.g., as described in connection with FIG. **5**), the UE **702** may mark the subsequent SDU as the new reference SDU and restart the common delivery timer based on a duration of the SDU's PDCP discard timer plus the common delivery window. In such aspects, at **720**, when the common delivery timer expires, all SDUs and PDUs associated with the particular N.sub.MM-SeqNum (e.g., all SDUs and PDUs associated with the couple SDUs) may be discarded, regardless of whether the individual PDU discard timer are still running or not.

[0094] In some aspects, if the PDCP discard timer is shorter than the remaining time of T.sub.ref (e.g., as described in connection with FIG. **6**), the UE may restart T.sub.ref, with a new duration equal to the PDCP discard timer of this SDU and restart, at **714**, the PDCP discard timer for every SDU in the group based on a minimum of a remaining time of its default PDCP discard timer or congestion specific PDCP discard timer and the new reference timer plus a duration based on the common delivery window (e.g., min (remaining time of its default PDCP discard timer, the new T.sub.ref+T.sub.MM_delivery), or start the PDCP discard timer with the duration equal to its default or congestion specific PDCP discard timer of its associated DRB. In such aspects, at **720**, the UE **702** may perform PDCP discard for individual SDUs when each SDU's own PDCP discard timer expires.

[0095] FIG. **8** is a flowchart **800** of a method of wireless communication. The method may be performed by a UE (e.g., the UE **104**; the apparatus **804**). The method provides enhancements for PDCP discard procedure for multi-modal traffic to improve efficiency of processing multi-modal traffic.

[0096] At **802**, the UE may receive, from a network entity, a plurality of coupled SDUs. For example, the UE **602** may receive, from a network entity, a plurality of coupled SDUs (e.g., including a first SDU **706** and subsequent SDU(s) **710**). In some aspects, **802** may be performed by multi-modal component **198**.

[0097] At **804**, the UE may start a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. For example, the UE **602** may start a timer (e.g., at **708**) associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. In some aspects, **804** may be performed by multi-modal component **198**.

[0098] At **806**, the UE may upon arrival of each subsequent SDU of the plurality of coupled SDUs, start a respective PDCP discard timer associated with the subsequent SDU. For example, the UE **602** may, upon arrival of each subsequent SDU of the plurality of coupled SDUs, start (e.g., **712**) a respective PDCP discard timer associated with the subsequent SDU. In some aspects, **806** may be performed by multi-modal component **198**.

[0099] At **808**, the UE may discard the plurality of coupled SDUs or a plurality of PDUs associated with the plurality of coupled SDUs based on a first expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on a second expiration of at least one respective PDCP discard timer associated with the at least one SDU. The use of the term “first” and “second” does not indicate a particular order in which the timer and a respective PDCP discard timer expires, and is included to differentiate between the different timers expiring. For example, the UE **602** may discard (e.g., at **720**) the plurality of coupled SDUs or a plurality of PDUs associated with the plurality of coupled SDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU. In some aspects, **808** may be performed by multi-modal component **198**.

[0100] In some aspects, the timer is based on a delivery time window associated with the plurality of coupled SDUs. In some aspects, the UE may identify the first SDU as a reference SDU based on the first SDU being not associated with the first MMSI (e.g., as described in connection with FIG. **5**), where the delivery timer is associated with the reference SDU. In some aspects, the UE may also generate (e.g., **709**) a second MMSI associated with the plurality of coupled SDUs upon reception of the first SDU. In some aspects, upon arrival of each subsequent SDU of the plurality of coupled SDUs, the UE may identify whether the subsequent SDU is associated with an earlier expiration time than the reference SDU associated with the second MMSI and restart the delivery timer based on identification that the subsequent SDU is associated with an earlier expiration time (e.g., **630**) than the reference SDU associated with the second MMSI.

[0101] In some aspects, the timer is a reference timer (e.g., **608**, **628**) based on a default PDCP discard timer associated with the first SDU (e.g., as described in connection with FIG. **6**). In some aspects, the UE may discard the at least one SDU of the plurality of coupled SDUs or the at least one PDU associated with the at least one SDU based on the expiration of the at least one respective PDCP discard timer associated with the at least one SDU. In some aspects, the UE may, upon arrival of each subsequent SDU of the plurality of coupled SDUs, if the default PDCP discard timer of the subsequent SDU is shorter than a remaining duration of the reference timer, restart the reference timer based on the default PDCP discard timer of the subsequent SDU and restart the respective PDCP discard timer associated with each respective SDU of the plurality of SDUs based on a minimum of the reference timer plus a delivery window associated with the plurality of coupled SDUs and a remaining time of the respective PDCP discard timer, or start the respective PDCP discard timer based on the default PDCP discard timer of the subsequent SDU. In some aspects, the respective PDCP discard timer is based a congestion state associated with the UE. In some aspects, the UE may recalculate the respective PDCP discard timer based on a change in the congestion state.

[0102] In some aspects, the UE may receive a configuration (e.g., **705**) configuring a plurality of QoS flows to be coupled based on a common MMSI, where the plurality of coupled SDUs are associated with the plurality of QOS flows. In some aspects, the configuration configuring the plurality of QoS flows to be coupled is a RRC configuration, and where the configuration configures a respective duration associated with each DRB associated with the plurality of coupled PDUs. In some aspects, the UE may identify the plurality of coupled SDUs based on a shared delivery deadline.

[0103] In some aspects, the UE may receive, from the network entity, assistance information for identification of the plurality of coupled SDUs, where the assistance information includes a set of real-time transport protocol (RTP) headers or a set of Internet protocol (IP) headers associated with the plurality of coupled SDUs.

[0104] In some aspects, the UE may receive a plurality of QoS flows associated with a common MMSI. In some aspects, the UE may generate (e.g., at **709**), for each group of SDUs in the plurality of QoS flows associated with a common delivery deadline, a multi-modal sequence number associated with the common delivery deadline.

[0105] In some aspects, the UE may transmit a set of groups of PDUs, where each group of PDUs in the set of groups of PDUs correspond to a respective group of SDUs in the plurality of QoS flows associated with the common delivery deadline, and where each group of PDUs in the set of groups of PDUs include a respective multi-modal sequence number associated with the respective common delivery deadline.

[0106] FIG. **9** is a diagram **900** illustrating an example of a hardware implementation for an apparatus **904**. The apparatus **904** may be a UE, a component of a UE, or may implement UE functionality. In some aspects, the apparatus **804** may include at least one cellular baseband processor **924** (also referred to as a modem) coupled to one or more transceivers **922** (e.g., cellular RF transceiver). The cellular baseband processor(s) **924** may include at least one on-chip memory **924′**. In some aspects, the apparatus **904** may further include one or more subscriber identity modules (SIM) cards **920** and at least one application processor **906** coupled to a secure digital (SD) card **908** and a screen **910**. The application processor(s) **906** may include on-chip memory **906′**. In some aspects, the apparatus **904** may further include a Bluetooth module **912**, a WLAN module **914**, an SPS module **916** (e.g., GNSS module), one or more sensor modules **918** (e.g., barometric pressure sensor/altimeter; motion sensor such as inertial measurement unit (IMU), gyroscope, and/or accelerometer(s); light detection and ranging (LIDAR), radio assisted detection and ranging (RADAR), sound navigation and ranging (SONAR), magnetometer, audio and/or other technologies used for positioning), additional memory modules **926**, a power supply **930**, and/or a camera **932**. The Bluetooth module **912**, the WLAN module **914**, and the SPS module **916** may include an on-chip transceiver (TRX) (or in some cases, just a receiver (RX)). The Bluetooth module **912**, the WLAN module **914**, and the SPS module **916** may include their own dedicated antennas and/or utilize the antennas **980** for communication. The cellular baseband processor(s) **924** communicates through the transceiver(s) **922** via one or more antennas **980** with the UE **104** and/or with an RU associated with a network entity **902**. The cellular baseband processor(s) **924** and the application processor(s) **906** may each include a computer-readable medium/memory **924′**, **906′**, respectively. The additional memory modules **926** may also be considered a computer-readable medium/memory. Each computer-readable medium/memory **924′**, **906′**, **926** may be non-transitory. The cellular baseband processor(s) **924** and the application processor(s) **906** are each responsible for general processing, including the execution of software stored on the computer-readable medium/memory. The software, when executed by the cellular baseband processor(s) **924**/application processor(s) **906**, causes the cellular baseband processor(s) **924**/application processor(s) **906** to perform the various functions described supra. The computer-readable medium/memory may also be used for storing data that is manipulated by the cellular baseband processor(s) **924**/application processor(s) **906** when executing software. The cellular baseband processor(s) **924**/application processor(s) **906** may be a component of the UE **350** and may include the at least one memory **360** and/or at least one of the TX processor **368**, the RX processor **356**, and the controller/processor **359**. In one configuration, the apparatus **904** may be at least one processor chip (modem and/or application) and include just the cellular baseband processor(s) **924** and/or the application processor(s) **906**, and in another configuration, the apparatus **904** may be the entire UE (e.g., see UE **350** of FIG. **3**) and include the additional modules of the apparatus **904**.

[0107] As discussed supra, the multi-modal component **198** may be configured to receive, from a network entity, a plurality of coupled service data units (SDUs). In some aspects, the multi-modal component **198** may be further configured to start a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. In some aspects, the multi-modal component **198** may be further configured to upon arrival of each subsequent SDU of the plurality of coupled SDUs, start a respective PDCP discard timer associated with the subsequent SDU. In some aspects, the multi-modal component **198** may be further configured to discard the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU. The multi-modal component **198** may be within the cellular baseband processor(s) **924**, the application processor(s) **906**, or both the cellular baseband processor(s) **924** and the application processor(s) **906**. The component **198** may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by one or more processors configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by one or more processors, or some combination thereof. When multiple processors are implemented, the multiple processors may perform the stated processes/algorithm individually or in combination. As shown, the apparatus **904** may include a variety of components configured for various functions. In one configuration, the apparatus **904**, and in particular the cellular baseband processor(s) **924** and/or the application processor(s) **906**, may include means for receiving, from a network entity, a plurality of coupled service data units (SDUs). In some aspects, the apparatus **904** may include means for starting a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs. In some aspects, the apparatus **904** may include means for upon arrival of each subsequent SDU of the plurality of coupled SDUs, starting a respective PDCP discard timer associated with the subsequent SDU. In some aspects, the apparatus **904** may include means for discarding the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU. In some aspects, the apparatus **904** may include means for identifying the first SDU as a reference SDU based on the first SDU being not associated with the first MMSI, where the delivery timer is associated with the reference SDU. In some aspects, the apparatus **904** may include means for generating a second MMSI associated with the plurality of coupled SDUs upon reception of the first SDU. In some aspects, the apparatus **904** may include means for upon arrival of each subsequent SDU of the plurality of coupled SDUs, identifying whether the subsequent SDU is associated with an earlier expiration time than the reference SDU associated with the second MMSI and restarting the delivery timer based on identification that the subsequent SDU is associated with an earlier expiration time than the reference SDU associated with the second MMSI. In some aspects, the apparatus **904** may include means for upon arrival of each subsequent SDU of the plurality of coupled SDUs, if the default PDCP discard timer of the subsequent SDU is shorter than a remaining duration of the reference timer, restarting the reference timer based on the default PDCP discard timer of the subsequent SDU and restarting the respective PDCP discard timer associated with each respective SDU of the plurality of SDUs based on a minimum of the reference timer plus a delivery window associated with the plurality of coupled SDUs and a remaining time of the respective PDCP discard timer or starting the respective PDCP discard timer based on the default PDCP discard timer of the subsequent SDU. In some aspects, the apparatus **904** may include means for recalculating the respective PDCP discard timer based on a change in the congestion state. In some aspects, the apparatus **904** may include means for receiving a configuration configuring a plurality of quality of service (QOS) flows to be coupled based on a common multi-modal service identifier (MMSI), where the plurality of coupled SDUs are associated with the plurality of QoS flows. In some aspects, the apparatus **904** may include means for identifying the plurality of coupled SDUs based on a shared delivery deadline. In some aspects, the apparatus **904** may include means for receiving, from the network entity, assistance information for identification of the plurality of coupled SDUs, where the assistance information includes a set of real-time transport protocol (RTP) headers or a set of Internet protocol (IP) headers associated with the plurality of coupled SDUs. In some aspects, the apparatus **904** may include means for receiving a plurality of quality of service (QOS) flows associated with a common multi-modal service identifier (MMSI). In some aspects, the apparatus **904** may include means for generating, for each group of SDUs in the plurality of QoS flows associated with a common delivery deadline, a multi-modal sequence number associated with the common delivery deadline. In some aspects, the apparatus **904** may include means for transmitting a set of groups of PDUs, where each group of PDUs in the set of groups of PDUs correspond to a respective group of SDUs in the plurality of QoS flows associated with the common delivery deadline, and where each group of PDUs in the set of groups of PDUs include a respective multi-modal sequence number associated with the respective common delivery deadline. The means may be the component **198** of the apparatus **904** configured to perform the functions recited by the means. As described supra, the apparatus **904** may include the TX processor **368**, the RX processor **356**, and the controller/processor **359**. As such, in one configuration, the means may be the TX processor **368**, the RX processor **356**, and/or the controller/processor **359** configured to perform the functions recited by the means.

[0108] It is understood that the specific order or hierarchy of blocks in the processes/flowcharts disclosed is an illustration of example approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes/flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not limited to the specific order or hierarchy presented.

[0109] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not limited to the aspects described herein, but are to be accorded the full scope consistent with the language claims. Reference to an element in the singular does not mean "one and only one" unless specifically so stated, but rather "one or more." Terms such as "if," "when," and "while" do not imply an immediate temporal relationship or reaction. That is, these phrases, e.g., "when," do not imply an immediate action in response to or during the occurrence of an action, but simply imply that if a condition is met then an action will occur, but without requiring a specific or immediate time constraint for the action to occur. The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term "some" refers to one or more. Combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as "at least one of A, B, or C," "one or more of A, B, or C," "at least one of A, B, and C," "one or more of A, B, and C," and "A, B, C, or any combination thereof" may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. Sets should be interpreted as a set of elements where the elements number one or more. Accordingly, for a set of X, X would include one or more elements. When at least one processor (i.e., a set of one or more processors P) is configured to perform a set of functions F, each processor of P may be configured to perform a subset S of F, where S.Math.F. Accordingly, each processor of the at least one processor may be configured to perform a particular subset of the set of functions, where the subset is the full set, a proper subset of the set, or an empty subset of the set. If a first apparatus receives data from or transmits data to a second apparatus, the data may be received/transmitted directly between the first and second apparatuses, or indirectly between the first and second apparatuses through a set of apparatuses. A device configured to "output" data, such as a transmission, signal, or message, may transmit the data, for example with a transceiver, or may send the data to a device that transmits the data. A device configured to "obtain" data, such as a transmission, signal, or message, may receive, for example with a transceiver, or may obtain the data from a device that receives the data. Information stored in a memory includes instructions and/or data. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are encompassed by the claims. Moreover, nothing disclosed herein is dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words "module," "mechanism," "element," "device," and the like may not be a substitute for the word "means." As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase "means for."

[0110] As used herein, the phrase "based on" shall not be construed as a reference to a closed set of information, one or more conditions, one or more factors, or the like. In other words, the phrase "based on A" (where "A" may be information, a condition, a factor, or the like) shall be construed as "based at least on A" unless specifically recited differently.

[0111] The following aspects are illustrative only and may be combined with other aspects or teachings described herein, without limitation.
[0112] Aspect 1 is a method for wireless communication performed by a user equipment (UE), including: receiving, from a network entity, a plurality of coupled service data units (SDUs); starting a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs; upon arrival of each subsequent SDU of the plurality of coupled SDUs, starting a respective PDCP discard timer associated with the subsequent SDU; and discarding the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on an expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on an expiration of at least one respective PDCP discard timer associated with the at least one SDU.
[0113] Aspect 2 is the method of aspect 1, where the timer is based on a delivery time window associated with the plurality of coupled SDUs.
[0114] Aspect 3 is the method of aspect 2, where the first SDU is not associated with a first multi-modal service identifier (MMSI), and further including: identifying the first SDU as a reference SDU based on the first SDU being not associated with the first MMSI, where the delivery timer is associated with the reference SDU.
[0115] Aspect 4 is the method of aspect 3, further including: generating a second MMSI associated with the plurality of coupled SDUs upon reception of the first SDU.
[0116] Aspect 5 is the method of any of aspects 3-4, further including: upon arrival of each subsequent SDU of the plurality of coupled SDUs: identifying whether the subsequent SDU is associated with an earlier expiration time than the reference SDU associated with the second MMSI; and restarting the delivery timer based on identification that the subsequent SDU is associated with an earlier expiration time than the reference SDU associated with the second MMSI.
[0117] Aspect 6 is the method of any of aspects 1-5, where the timer is a reference timer based on a default PDCP discard timer associated with the first SDU.
[0118] Aspect 7 is the method of aspect 6, including discarding the at least one SDU of the plurality of coupled SDUs or the at least one PDU associated with the at least one SDU based on the expiration of the at least one respective PDCP discard timer associated with the at least one SDU.
[0119] Aspect 8 is the method of aspect 7, further including: upon arrival of each subsequent SDU of the plurality of coupled SDUs: if the default PDCP discard timer of the subsequent SDU is shorter than a remaining duration of the reference timer, restarting the reference timer based on the default PDCP discard timer of the subsequent SDU and restarting the respective PDCP discard timer associated with each respective SDU of the plurality of SDUs based on a minimum of the reference timer plus a delivery window associated with the plurality of coupled SDUs and a remaining time of the respective PDCP discard timer; or starting the respective PDCP discard timer based on the default PDCP discard timer of the subsequent SDU.
[0120] Aspect 9 is the method of aspect 8, where the respective PDCP discard timer is based a congestion state associated with the UE.
[0121] Aspect 10 is the method of aspect 9, further including: recalculating the respective PDCP discard timer based on a change in the congestion state.
[0122] Aspect 11 is the method of any of aspects 1-10, further including: receiving a configuration configuring a plurality of quality of service (QOS) flows to be coupled based on a common multi-modal service identifier (MMSI), where the plurality of coupled SDUs are associated with the plurality of QoS flows.
[0123] Aspect 12 is the method of aspect 11, where the configuration configuring the plurality of QoS flows to be coupled is a radio resource control (RRC) configuration, and where the configuration configures a respective duration associated with each data radio bearer (DRB) associated with the plurality of coupled PDUs.

[0124] Aspect 13 is the method of any of aspects 1-12, further including: identifying the plurality of coupled SDUs based on a shared delivery deadline.
[0125] Aspect 14 is the method of aspect 13, further including: receiving, from the network entity, assistance information for identification of the plurality of coupled SDUs, where the assistance information includes a set of real-time transport protocol (RTP) headers or a set of Internet protocol (IP) headers associated with the plurality of coupled SDUs.
[0126] Aspect 15 is the method of any of aspects 1-14, further including: receiving a plurality of quality of service (QOS) flows associated with a common multi-modal service identifier (MMSI); and generating, for each group of SDUs in the plurality of QoS flows associated with a common delivery deadline, a multi-modal sequence number associated with the common delivery deadline.
[0127] Aspect 16 is the method of aspect 15, further including: transmitting a set of groups of PDUs, where each group of PDUs in the set of groups of PDUs correspond to a respective group of SDUs in the plurality of QoS flows associated with the common delivery deadline, and where each group of PDUs in the set of groups of PDUs include a respective multi-modal sequence number associated with the respective common delivery deadline.
[0128] Aspect 17 is an apparatus for wireless communication at a wireless device including at least one memory and at least one processor coupled to the at least one memory and, the at least one processor based at least in part on information stored in the at least one memory, the at least one processor is configured to implement any of aspects 1 to 16.
[0129] Aspect 18 is the apparatus of aspect 17, further including one or more transceivers or one or more antennas coupled to the at least one processor.
[0130] Aspect 19 is an apparatus for wireless communication at a device including means for implementing any of aspects 1 to 16.
[0131] Aspect 20 is a computer-readable medium (e.g., a non-transitory computer-readable medium) storing computer executable code, where the code when executed by at least one processor causes the at least one processor to implement any of aspects 1 to 16.

Claims

1. An apparatus for wireless communication at a user equipment (UE), comprising: at least one memory; and at least one processor coupled to the at least one memory, based at least in part on information stored in the at least one memory, the at least one processor is configured to cause the UE to: receive, from a network entity, a plurality of coupled service data units (SDUs); start a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs; upon arrival of each subsequent SDU of the plurality of coupled SDUs, start a respective PDCP discard timer associated with a subsequent SDU; and discard the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on a first expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on a second expiration of at least one respective PDCP discard timer associated with the at least one SDU.
2. The apparatus of claim 1, wherein the timer is based on a delivery time window associated with the plurality of coupled SDUs.
3. The apparatus of claim 2, wherein the first SDU is not associated with a first multi-modal service identifier (MMSI), and wherein the at least one processor is further configured to cause the UE to: identify the first SDU as a reference SDU based on the first SDU being not associated with the first MMSI, wherein the timer is associated with the reference SDU.
4. The apparatus of claim 3, wherein the at least one processor is further configured to cause the UE to: generate a second MMSI associated with the plurality of coupled SDUs upon reception of the first SDU.
5. The apparatus of claim 4, wherein the at least one processor is further configured to cause the

UE to: upon the arrival of each subsequent SDU of the plurality of coupled SDUs: identify whether the subsequent SDU is associated with an earlier expiration time than the reference SDU associated with the second MMSI; and restart the delivery timer based on an identification that the subsequent SDU is associated with the earlier expiration time than the reference SDU associated with the second MMSI.

6. The apparatus of claim 1, wherein the timer is a reference timer based on a default PDCP discard timer associated with the first SDU.

7. The apparatus of claim 6, wherein the at least one processor is configured to cause the UE to discard the at least one SDU of the plurality of coupled SDUs or the at least one PDU associated with the at least one SDU based on the second expiration of the at least one respective PDCP discard timer associated with the at least one SDU.

8. The apparatus of claim 7, wherein the at least one processor is further configured to cause the UE to: upon arrival of each subsequent SDU of the plurality of coupled SDUs: if the default PDCP discard timer of the subsequent SDU is shorter than a remaining duration of the reference timer, restart the reference timer based on the default PDCP discard timer of the subsequent SDU and restart the respective PDCP discard timer associated with each respective SDU of the plurality of coupled SDUs based on a minimum of the reference timer plus a delivery window associated with the plurality of coupled SDUs and a remaining time of the respective PDCP discard timer; or start the respective PDCP discard timer based on the default PDCP discard timer of the subsequent SDU.

9. The apparatus of claim 8, wherein the respective PDCP discard timer is based a congestion state associated with the UE.

10. The apparatus of claim 9, wherein the at least one processor is further configured to cause the UE to: recalculate the respective PDCP discard timer based on a change in the congestion state.

11. The apparatus of claim 1, wherein the at least one processor is further configured to cause the UE to: receive a configuration configuring a plurality of quality of service (QOS) flows to be coupled based on a common multi-modal service identifier (MMSI), wherein the plurality of coupled SDUs are associated with the plurality of QoS flows.

12. The apparatus of claim 11, wherein the configuration configuring the plurality of QoS flows to be coupled is a radio resource control (RRC) configuration, and wherein the configuration configures a respective duration associated with each data radio bearer (DRB) associated with the plurality of coupled PDUs.

13. The apparatus of claim 1, wherein the at least one processor is further configured to cause the UE to: identify the plurality of coupled SDUs based on a shared delivery deadline.

14. The apparatus of claim 13, wherein the at least one processor is further configured to cause the UE to: receive, from the network entity, assistance information for identification of the plurality of coupled SDUs, wherein the assistance information comprises a set of real-time transport protocol (RTP) headers or a set of Internet protocol (IP) headers associated with the plurality of coupled SDUs.

15. The apparatus of claim 1, wherein the at least one processor is further configured to cause the UE to: receive a plurality of quality of service (QOS) flows associated with a common multi-modal service identifier (MMSI); and generate, for each group of SDUs in the plurality of QoS flows associated with a common delivery deadline, a multi-modal sequence number associated with the common delivery deadline.

16. The apparatus of claim 15, wherein the at least one processor is further configured to cause the UE to: transmit a set of groups of PDUs, wherein each group of PDUs in the set of groups of PDUs correspond to a respective group of SDUs in the plurality of QoS flows associated with the common delivery deadline, and wherein each group of PDUs in the set of groups of PDUs include a respective multi-modal sequence number associated with a respective common delivery deadline.

17. A method for wireless communication performed by a user equipment (UE), comprising:

receiving, from a network entity, a plurality of coupled service data units (SDUs); starting a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs; upon arrival of each subsequent SDU of the plurality of coupled SDUs, starting a respective PDCP discard timer associated with the subsequent SDU; and discarding the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on a first expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on a second expiration of at least one respective PDCP discard timer associated with the at least one SDU.

18. The method of claim 17, wherein the timer is based on a delivery time window associated with the plurality of coupled SDUs.

19. The method of claim 17, wherein the timer is a reference timer based on a default PDCP discard timer associated with the first SDU.

20. An apparatus for wireless communication at a user equipment (UE), comprising: means for receiving, from a network entity, a plurality of coupled service data units (SDUs); means for starting a timer associated with the plurality of coupled SDUs upon arrival of a first SDU of the plurality of coupled SDUs; means for starting, upon arrival of each subsequent SDU of the plurality of coupled SDUs, a respective PDCP discard timer associated with a subsequent SDU; and means for discarding the plurality of coupled SDUs or a plurality of protocol data units (PDUs) associated with the plurality of coupled SDUs based on a first expiration of the timer or discard at least one SDU of the plurality of coupled SDUs or at least one PDU associated with the at least one SDU based on a second expiration of at least one respective PDCP discard timer associated with the at least one SDU.