

PDU SET IMPORTANCE MARKING IN QoS FLOWS IN A WIRELESS COMMUNICATION NETWORK

Field

- 5 [0001] The subject matter disclosed herein relates generally to the field of implementing PDU Set importance marking in QoS flows in a wireless communication network. This document defines a User Plane Function, a method performed by a User Plane Function, an Application Function, and a method performed by an Application Function.

10 **Introduction**

- [0002] In the context of XR media traffic, 3GPP System Architecture WG recently considered the concept of an XR multimedia session comprising multiplexed media streams. One or more PDUs corresponding to one or more media streams may not be able to be marked by the Application Server (AS) with the 3GPP PDU Set marking information necessary for XR traffic QoS handling with application data unit awareness 15 over the 5GS. On receiving such an unmarked PDU, the User Plane Function (UPF) could compensate for the lack of PDU Set information for the unmarked PDUs by marking individual unmarked PDUs as if they were the sole members of their own PDU Set and adding corresponding PDU Set information, i.e., PDU Set Sequence Number, PDU Sequence Number within a PDU Set, end PDU indication of a PDU Set, PDU Set importance. 20

- [0003] The PDU Set importance information marks the relative importance of a PDU Set to other PDU Sets transported over the 5GS under the same QoS Flow with the same PDU Set requirements. Therefore, the PDU Set importance information of UPF marked PDU Sets carries critical value to the 5GS treatment of XR traffic as the NG-RAN may generally use the importance value to determine prioritization and dropping strategies for resource allocation under congestion over the 5GS air-interface. 25

Summary

- 30 [0004] A problem with allocating a default importance value to PDU Sets marked by the UPF is that this may hinder any benefit of QoS Flow PDU Set handling across the 5GS, and, over the Next Generation Radio Access Network (NG-RAN).
[0005] Disclosed herein are procedures for PDU Set importance marking in QoS flows in a wireless communication network. Said procedures may be implemented by a User

Plane Function, a method performed by a User Plane Function, an Application Function, and a method performed by an Application Function.

- [0006] Accordingly, there is provided a User Plane Function (UPF), comprising a processor and a memory coupled with the processor, the memory comprising
- 5 instructions executable by the processor to cause the UPF to: receive a configuration, the configuration comprising a protocol description including one or more media stream components and at least one default PDU Set importance value; and receive a protocol data unit (PDU) in a downlink direction wherein the received PDU is subject to PDU Set processing according to the configuration. The UPF is further caused to determine
- 10 whether: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set; and to determine a PDU Set importance information value, the determination based on the at least one default PDU Set importance value. The UPF is further caused to create a header for the
- 15 received PDU, the header including PDU Set information and the determined PDU Set importance information value if either: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description of the received configuration, but the received PDU is not part of a PDU Set; and to route the received PDU and the header to a radio access network.
- 20 [0007] There is further provided a method performed by a User Plane Function (UPF), the method comprising receiving a configuration, the configuration comprising a protocol description including one or more media stream components and at least one default PDU Set importance value; and receiving a protocol data unit (PDU) in a downlink direction wherein the received PDU is subject to PDU Set processing
- 25 according to the configuration. The method further comprises determining whether: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set; and determining a PDU Set importance information value, the determination based on the at least one default PDU Set
- 30 importance value. The method further still comprises creating a header for the received PDU, the header including PDU Set information and the determined PDU Set importance information value if either: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description

of the received configuration, but the received PDU is not part of a PDU Set; and routing the received PDU and the header to a radio access network.

- [0008] There is further provided an Application Function (AF) comprising a processor and a memory coupled with the processor, the memory comprising instructions
- 5 executable by the processor to cause the AF to: determine a configuration for a service data flow session for an application server (AS) with PDU Set processing based on at least a protocol description including one or more media streams components and at least one request for a default PDU Set importance value; set the at least one requested default PDU Set importance value as either common to each of the one or more media
- 10 streams components of the protocol description, or individual for each of the one or more media streams components of the protocol description; and communicate the determined configuration to one of a Policy Control Function (PCF) and a Network Exposure Function (NEF) to establish the service data flow session with PDU Set processing over a mobile core network.
- 15 [0009] There is further still provided a method performed at an Application Function (AF), the method comprising: determining a configuration for a service data flow session for an application server (AS) with PDU Set processing based on at least a protocol description including one or more media streams components and at least one request for a default PDU Set importance value; setting the at least one requested default PDU
- 20 Set importance value as either common to each of the one or more media streams components of the protocol description, or individual for each of the one or more media streams components of the protocol description; and communicating the determined configuration to one of a Policy Control Function (PCF) and a Network Exposure Function (NEF) to establish the service data flow session with PDU Set processing over
- 25 a mobile core network.

Brief description of the drawings

- [0010] In order to describe the manner in which advantages and features of the disclosure can be obtained, a description of the disclosure is rendered by reference to
- 30 certain apparatus and methods which are illustrated in the appended drawings. Each of these drawings depict only certain aspects of the disclosure and are not therefore to be considered to be limiting of its scope. The drawings may have been simplified for clarity and are not necessarily drawn to scale.

[0011] Methods and apparatus for PDU Set importance marking in QoS flows in a wireless communication network will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 depicts an embodiment of a wireless communication system for PDU Set importance marking in QoS flows in a wireless communication network;

Figure 2 depicts a user equipment apparatus that may be used for implementing the methods described herein;

Figure 3 depicts further details of the network node that may be used for implementing the methods described herein;

Figure 4 provides an overview of the RTP and RTCP stack;

Figure 5 illustrates an overview of the WebRTC stack;

Figures 6a and 6b illustrate a packet format and header information for an RTP packet and an SRTP packet, respectively;

Figure 7 illustrates RTP/SRTP header extension format and syntax;

Figure 8 illustrates an overview of a core network XRM architecture handling of PDU Sets;

Figures 9a to 9d illustrate 5GS PDU Set-aware QoS handling framework description of PDU Set to QoS flow to DRB mappings;

Figures 10a and 10b illustrate one-byte and two-byte RTP Header Extension for the marking of PDU Set information, respectively;

Figure 11 illustrates an example of a scenario comprising different AF sessions for an XR video application and a non-XR application being multiplexed by a 5GS;

Figure 12 illustrates an example scenario comprising one AF session for an XR application served over WebRTC, or alike protocols, where the audio and the video are transmitted in multiplex over one RTP session for the XR application;

Figure 13 illustrates a method in a User Plane Function; and

Figure 14 illustrates a method in an Application Function.

Detailed description

[0012] A problem with allocating a default importance value to PDU Sets marked by the UPF is that this may hinder any benefit of QoS Flow PDU Set handling across the 5GS, and, over the Next Generation Radio Access Network (NG-RAN).

[0013] Prior to delving further into the details of the techniques presented herein, note that, as will be appreciated by one skilled in the art, aspects of this disclosure may be

embodied as a system, apparatus, method, or program product. Accordingly, arrangements described herein may be implemented in an entirely hardware form, an entirely software form (including firmware, resident software, micro-code, etc.) or a form combining software and hardware aspects.

5 [0014] For example, the disclosed methods and apparatus may be implemented as a hardware circuit comprising custom very-large-scale integration (“VLSI”) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. The disclosed methods and apparatus may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable
10 array logic, programmable logic devices, or the like. As another example, the disclosed methods and apparatus may include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function.

[0015] Furthermore, the methods and apparatus may take the form of a program product embodied in one or more computer readable storage devices storing machine
15 readable code, computer readable code, and/or program code, referred hereafter as code. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In certain arrangements, the storage devices only employ signals for accessing code.

[0016] Any combination of one or more computer readable medium may be utilized.
20 The computer readable medium may be a computer readable storage medium. The computer readable storage medium may be a storage device storing the code. The storage device may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

25 [0017] More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random-access memory (“RAM”), a read-only memory (“ROM”), an erasable programmable read-only memory (“EPROM” or Flash memory), a portable compact disc read-only memory (“CD-ROM”), an optical storage device, a
30 magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store, a program for use by or in connection with an instruction execution system, apparatus, or device.

[0018] Reference throughout this specification to an example of a particular method or apparatus, or similar language, means that a particular feature, structure, or characteristic described in connection with that example is included in at least one implementation of the method and apparatus described herein. Thus, reference to features of an example of a particular method or apparatus, or similar language, may, but do not necessarily, all refer to the same example, but mean “one or more but not all examples” unless expressly specified otherwise. The terms “including”, “comprising”, “having”, and variations thereof, mean “including but not limited to”, unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise. The terms “a”, “an”, and “the” also refer to “one or more”, unless expressly specified otherwise.

[0019] As used herein, a list with a conjunction of “and/or” includes any single item in the list or a combination of items in the list. For example, a list of A, B and/or C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology “one or more of” includes any single item in the list or a combination of items in the list. For example, one or more of A, B and C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology “one of” includes one, and only one, of any single item in the list. For example, “one of A, B and C” includes only A, only B or only C and excludes combinations of A, B and C. As used herein, “a member selected from the group consisting of A, B, and C” includes one and only one of A, B, or C, and excludes combinations of A, B, and C.” As used herein, “a member selected from the group consisting of A, B, and C and combinations thereof” includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C.

[0020] Furthermore, the described features, structures, or characteristics described herein may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions, database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of the disclosure. One skilled in the relevant art will recognize, however, that the disclosed methods and apparatus may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-

known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the disclosure.

[0021] Aspects of the disclosed method and apparatus are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and program products. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams and/or schematic block diagrams, can be implemented by code. This code may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the schematic flowchart diagrams and/or schematic block diagrams.

[0022] The code may also be stored in a storage device that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function/act specified in the schematic flowchart diagrams and/or schematic block diagrams.

[0023] The code may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus, or other devices to produce a computer implemented process such that the code which executes on the computer or other programmable apparatus provides processes for implementing the functions/acts specified in the schematic flowchart diagrams and/or schematic block diagram.

[0024] The schematic flowchart diagrams and/or schematic block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods, and program products. In this regard, each block in the schematic flowchart diagrams and/or schematic block diagrams may represent a module, segment, or portion of code, which includes one or more executable instructions of the code for implementing the specified logical function(s).

[0025] It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the

functionality involved. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, of the illustrated Figures.

[0026] The description of elements in each figure may refer to elements of proceeding
5 Figures. Like numbers refer to like elements in all Figures.

[0027] Figure 1 depicts an embodiment of a wireless communication system 100 for PDU Set Importance marking in QoS Flows in a wireless communications network. In one embodiment, the wireless communication system 100 includes remote units 102 and network units 104. Even though a specific number of remote units 102 and network
10 units 104 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 102 and network units 104 may be included in the wireless communication system 100. The wireless communication system may comprise a wireless communication network and at least one wireless communication device. The wireless communication device is typically a 3GPP User Equipment (UE). The wireless
15 communication network may comprise at least one network node. The network node may be a network unit.

[0028] In one embodiment, the remote units 102 may include computing devices, such as desktop computers, laptop computers, personal digital assistants (“PDAs”), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet),
20 set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), aerial vehicles, drones, or the like. In some embodiments, the remote units 102 include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units 102 may be referred to as subscriber units, mobiles, mobile
25 stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, UE, user terminals, a device, or by other terminology used in the art. The remote units 102 may communicate directly with one or more of the network units 104 via UL communication signals. In certain embodiments, the remote units 102 may communicate directly with other remote units 102 via sidelink communication.

[0029] The network units 104 may be distributed over a geographic region. In certain embodiments, a network unit 104 may also be referred to as an access point, an access terminal, a base, a base station, a Node-B, an eNB, a gNB, a Home Node-B, a relay node, a device, a core network, an aerial server, a radio access node, an AP, NR, a network
30 entity, an Access and Mobility Management Function (“AMF”), a Unified Data

Management Function (“UDM”), a Unified Data Repository (“UDR”), a UDM/UDR, a Policy Control Function (“PCF”), a Radio Access Network (“RAN”), an Network Slice Selection Function (“NSSF”), an operations, administration, and management (“OAM”), a session management function (“SMF”), a user plane function (“UPF”), an application
5 function, an authentication server function (“AUSF”), security anchor functionality (“SEAF”), trusted non-3GPP gateway function (“TNGF”), an application function, a service enabler architecture layer (“SEAL”) function, a vertical application enabler server, an edge enabler server, an edge configuration server, a mobile edge computing platform function, a mobile edge computing application, an application data analytics enabler
10 server, a SEAL data delivery server, a middleware entity, a network slice capability management server, or by any other terminology used in the art. The network units 104 are generally part of a radio access network that includes one or more controllers communicably coupled to one or more corresponding network units 104. The radio access network is generally communicably coupled to one or more core networks, which
15 may be coupled to other networks, like the Internet and public switched telephone networks, among other networks. These and other elements of radio access and core networks are not illustrated but are well known generally by those having ordinary skill in the art.

[0030] In one implementation, the wireless communication system 100 is compliant with
20 New Radio (NR) protocols standardized in 3GPP, wherein the network unit 104 transmits using an Orthogonal Frequency Division Multiplexing (“OFDM”) modulation scheme on the downlink (DL) and the remote units 102 transmit on the uplink (UL) using a Single Carrier Frequency Division Multiple Access (“SC-FDMA”) scheme or an OFDM scheme. More generally, however, the wireless communication system 100 may
25 implement some other open or proprietary communication protocol, for example, WiMAX, IEEE 802.11 variants, GSM, GPRS, UMTS, LTE variants, CDMA2000, Bluetooth®, ZigBee, Sigfox, LoraWAN among other protocols. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

30 [0031] The network units 104 may serve a number of remote units 102 within a serving area, for example, a cell or a cell sector via a wireless communication link. The network units 104 transmit DL communication signals to serve the remote units 102 in the time, frequency, and/or spatial domain.

- [0032] Figure 2 depicts a user equipment apparatus 200 that may be used for implementing the methods described herein. The user equipment apparatus 200 is used to implement one or more of the solutions described herein. The user equipment apparatus 200 is in accordance with one or more of the user equipment apparatuses described in embodiments herein. In particular, the user equipment apparatus 200 may comprise a remote unit 102, a UE 835, 1035 or 1135 as described herein. The user equipment apparatus 200 includes a processor 205, a memory 210, an input device 215, an output device 220, and a transceiver 225.
- [0033] The input device 215 and the output device 220 may be combined into a single device, such as a touchscreen. In some implementations, the user equipment apparatus 200 does not include any input device 215 and/or output device 220. The user equipment apparatus 200 may include one or more of: the processor 205, the memory 210, and the transceiver 225, and may not include the input device 215 and/or the output device 220.
- [0034] As depicted, the transceiver 225 includes at least one transmitter 230 and at least one receiver 235. The transceiver 225 may communicate with one or more cells (or wireless coverage areas) supported by one or more base units. The transceiver 225 may be operable on unlicensed spectrum. Moreover, the transceiver 225 may include multiple UE panels supporting one or more beams. Additionally, the transceiver 225 may support at least one network interface 240 and/or application interface 245. The application interface(s) 245 may support one or more APIs. The network interface(s) 240 may support 3GPP reference points, such as Uu, N1, PC5, etc. Other network interfaces 240 may be supported, as understood by one of ordinary skill in the art.
- [0035] The processor 205 may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 205 may be a microcontroller, a microprocessor, a central processing unit (“CPU”), a graphics processing unit (“GPU”), an auxiliary processing unit, a field programmable gate array (“FPGA”), or similar programmable controller. The processor 205 may execute instructions stored in the memory 210 to perform the methods and routines described herein. The processor 205 is communicatively coupled to the memory 210, the input device 215, the output device 220, and the transceiver 225.
- [0036] The processor 205 may control the user equipment apparatus 200 to implement the user equipment apparatus behaviors described herein. The processor 205 may include an application processor (also known as “main processor”) which manages

application-domain and operating system (“OS”) functions and a baseband processor (also known as “baseband radio processor”) which manages radio functions.

[0037] The memory 210 may be a computer readable storage medium. The memory 210 may include volatile computer storage media. For example, the memory 210 may include
5 a RAM, including dynamic RAM (“DRAM”), synchronous dynamic RAM (“SDRAM”), and/or static RAM (“SRAM”). The memory 210 may include non-volatile computer storage media. For example, the memory 210 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. The memory 210 may include both volatile and non-volatile computer storage media.

10 [0038] The memory 210 may store data related to implement a traffic category field as described herein. The memory 210 may also store program code and related data, such as an operating system or other controller algorithms operating on the apparatus 200.

[0039] The input device 215 may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. The input device
15 215 may be integrated with the output device 220, for example, as a touchscreen or similar touch-sensitive display. The input device 215 may include a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. The input device 215 may include two or more different devices, such as a keyboard and a touch panel.

20 [0040] The output device 220 may be designed to output visual, audible, and/or haptic signals. The output device 220 may include an electronically controllable display or display device capable of outputting visual data to a user. For example, the output device 220 may include, but is not limited to, a Liquid Crystal Display (“LCD”), a Light-Emitting Diode (“LED”) display, an Organic LED (“OLED”) display, a projector, or
25 similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 220 may include a wearable display separate from, but communicatively coupled to, the rest of the user equipment apparatus 200, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 220 may be a component of a smart phone, a personal digital assistant, a
30 television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0041] The output device 220 may include one or more speakers for producing sound. For example, the output device 220 may produce an audible alert or notification (e.g., a beep or chime). The output device 220 may include one or more haptic devices for

producing vibrations, motion, or other haptic feedback. All, or portions, of the output device 220 may be integrated with the input device 215. For example, the input device 215 and output device 220 may form a touchscreen or similar touch-sensitive display. The output device 220 may be located near the input device 215.

5 [0042] The transceiver 225 communicates with one or more network functions of a mobile communication network via one or more access networks. The transceiver 225 operates under the control of the processor 205 to transmit messages, data, and other signals and also to receive messages, data, and other signals. For example, the processor 205 may selectively activate the transceiver 225 (or portions thereof) at particular times in
10 order to send and receive messages.

[0043] The transceiver 225 includes at least one transmitter 230 and at least one receiver 235. The one or more transmitters 230 may be used to provide uplink communication signals to a base unit of a wireless communication network. Similarly, the one or more receivers 235 may be used to receive downlink communication signals from the base
15 unit. Although only one transmitter 230 and one receiver 235 are illustrated, the user equipment apparatus 200 may have any suitable number of transmitters 230 and receivers 235. Further, the transmitter(s) 230 and the receiver(s) 235 may be any suitable type of transmitters and receivers. The transceiver 225 may include a first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio
20 spectrum and a second transmitter/receiver pair used to communicate with a mobile communication network over unlicensed radio spectrum.

[0044] The first transmitter/receiver pair may be used to communicate with a mobile communication network over licensed radio spectrum and the second transmitter/receiver pair used to communicate with a mobile communication network
25 over unlicensed radio spectrum may be combined into a single transceiver unit, for example a single chip performing functions for use with both licensed and unlicensed radio spectrum. The first transmitter/receiver pair and the second transmitter/receiver pair may share one or more hardware components. For example, certain transceivers 225, transmitters 230, and receivers 235 may be implemented as physically separate
30 components that access a shared hardware resource and/or software resource, such as for example, the network interface 240.

[0045] One or more transmitters 230 and/or one or more receivers 235 may be implemented and/or integrated into a single hardware component, such as a multi-transceiver chip, a system-on-a-chip, an Application-Specific Integrated Circuit (“ASIC”),

or other type of hardware component. One or more transmitters 230 and/or one or more receivers 235 may be implemented and/or integrated into a multi-chip module. Other components such as the network interface 240 or other hardware components/circuits may be integrated with any number of transmitters 230 and/or receivers 235 into a single chip. The transmitters 230 and receivers 235 may be logically configured as a transceiver 225 that uses one more common control signals or as modular transmitters 230 and receivers 235 implemented in the same hardware chip or in a multi-chip module.

[0046] Figure 3 depicts further details of the network node 300 that may be used for implementing the methods described herein. The network node 300 may be one implementation of an entity in the wireless communication network, e.g. in one or more of the wireless communication networks described herein. The network node 300 may comprise a network unit 104, or a User Plane Function (UPF) as described herein such as UPF 1040 and 1140. The network node 300 includes a processor 305, a memory 310, an input device 315, an output device 320, and a transceiver 325.

[0047] The input device 315 and the output device 320 may be combined into a single device, such as a touchscreen. In some implementations, the network node 300 does not include any input device 315 and/or output device 320. The network node 300 may include one or more of: the processor 305, the memory 310, and the transceiver 325, and may not include the input device 315 and/or the output device 320.

[0048] As depicted, the transceiver 325 includes at least one transmitter 330 and at least one receiver 335. Here, the transceiver 325 communicates with one or more remote units 200. Additionally, the transceiver 325 may support at least one network interface 340 and/or application interface 345. The application interface(s) 345 may support one or more APIs. The network interface(s) 340 may support 3GPP reference points, such as Uu, N1, N2, N3 and N6. Other network interfaces 340 may be supported, as understood by one of ordinary skill in the art.

[0049] The processor 305 may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 305 may be a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or similar programmable controller. The processor 305 may execute instructions stored in the memory 310 to perform the methods and routines described herein. The processor 305 is communicatively coupled to the memory 310, the input device 315, the output device 320, and the transceiver 325.

[0050] The memory 310 may be a computer readable storage medium. The memory 310 may include volatile computer storage media. For example, the memory 310 may include a RAM, including dynamic RAM (“DRAM”), synchronous dynamic RAM (“SDRAM”), and/or static RAM (“SRAM”). The memory 310 may include non-volatile computer storage media. For example, the memory 310 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. The memory 310 may include both volatile and non-volatile computer storage media.

[0051] The memory 310 may store data related to establishing a multipath unicast link and/or mobile operation. For example, the memory 310 may store parameters, configurations, resource assignments, policies, and the like, as described herein. The memory 310 may also store program code and related data, such as an operating system or other controller algorithms operating on the network node 300.

[0052] The input device 315 may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. The input device 315 may be integrated with the output device 320, for example, as a touchscreen or similar touch-sensitive display. The input device 315 may include a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. The input device 315 may include two or more different devices, such as a keyboard and a touch panel.

[0053] The output device 320 may be designed to output visual, audible, and/or haptic signals. The output device 320 may include an electronically controllable display or display device capable of outputting visual data to a user. For example, the output device 320 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 320 may include a wearable display separate from, but communicatively coupled to, the rest of the network node 300, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 320 may be a component of a smart phone, a personal digital assistant, a television, a table computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0054] The output device 320 may include one or more speakers for producing sound. For example, the output device 320 may produce an audible alert or notification (e.g., a beep or chime). The output device 320 may include one or more haptic devices for producing vibrations, motion, or other haptic feedback. All, or portions, of the output

device 320 may be integrated with the input device 315. For example, the input device 315 and output device 320 may form a touchscreen or similar touch-sensitive display. The output device 320 may be located near the input device 315.

[0055] The transceiver 325 includes at least one transmitter 330 and at least one receiver 335. The one or more transmitters 330 may be used to communicate with the UE, as described herein. Similarly, the one or more receivers 335 may be used to communicate with network functions in the PLMN and/or RAN, as described herein. Although only one transmitter 330 and one receiver 335 are illustrated, the network node 300 may have any suitable number of transmitters 330 and receivers 335. Further, the transmitter(s) 330 and the receiver(s) 335 may be any suitable type of transmitters and receivers.

[0056] In the context of XR media traffic, 3GPP System Architecture WG recently considered the concept of an XR multimedia session comprising multiplexed media streams. One or more PDUs corresponding to one or more media streams may not be able to be marked by the Application Server (AS) with the 3GPP PDU Set marking information necessary for XR traffic QoS handling with application data unit awareness over the 5GS. On receiving such an unmarked PDU, the User Plane Function (UPF) could compensate for the lack of PDU Set information for the unmarked PDUs by marking individual unmarked PDUs as if they were the sole members of their own PDU Set and adding corresponding PDU Set information, i.e., PDU Set Sequence Number, PDU Sequence Number within a PDU Set, end PDU indication of a PDU Set, PDU Set importance.

[0057] The PDU Set importance information marks the relative importance of a PDU Set to other PDU Sets transported over the 5GS under the same QoS Flow with the same PDU Set requirements. Therefore, the PDU Set importance information of UPF marked PDU Sets carries critical value to the 5GS treatment of XR traffic as the NG-RAN may generally use the importance value to determine prioritization and dropping strategies for resource allocation under congestion over the 5GS air-interface.

[0058] Consequently, allocating a static default importance value to PDU Sets marked by the UPF may be suboptimal and hinder any benefit of QoS Flow PDU Set handling across the 5GS, and, over the Next Generation Radio Access Network (NG-RAN). This problem tends to be solved by the methods and apparatuses presented herein by way of a proposed mechanism and methods for the UPF to be configured with specific, and even optimized, default PDU Set importance values for the PDU Sets marked by the UPF on the fly for XR multimedia sessions.

[0059] Hereafter eXtended Reality (XR) is used as an umbrella term for different types of realities, of which Virtual Reality, Augmented Reality, and Mixed Reality are examples.

[0060] Virtual Reality (VR) is a rendered version of a delivered visual and audio scene.

The rendering is in this case designed to mimic the visual and audio sensory stimuli of the real world as naturally as possible to an observer or user as they move within the limits defined by the application. Virtual reality usually, but not necessarily, requires a user to wear a head mounted display (HMD), to completely replace the user's field of view with a simulated visual component, and to wear headphones, to provide the user with the accompanying audio. Some form of head and motion tracking of the user in VR is usually also necessary to allow the simulated visual and audio components to be updated to ensure that, from the user's perspective, items and sound sources remain consistent with the user's movements. In some implementations additional means to interact with the virtual reality simulation may be provided but are not strictly necessary.

[0061] Augmented Reality (AR) is when a user is provided with additional information or artificially generated items, or content overlaid upon their current environment. Such additional information or content will usually be visual and/or audible and their observation of their current environment may be direct, with no intermediate sensing, processing, and rendering, or indirect, where their perception of their environment is relayed via sensors and may be enhanced or processed.

[0062] Mixed Reality (MR) is an advanced form of AR where some virtual elements are inserted into the physical scene with the intent to provide the illusion that these elements are part of the real scene.

[0063] XR refers to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. It includes representative forms such as AR, MR and VR and the areas interpolated among them. The levels of virtuality range from partially sensory inputs to fully immersive VR. In some circles, a key aspect of XR is considered to be the extension of human experiences especially relating to the senses of existence (represented by VR) and the acquisition of cognition (represented by AR).

[0064] In 3GPP Release 17, SA4 analyzed the XR traffic model, as described in 3GPP Technical Report TR 26.926 (v1.3.0 – Jan 2023) titled "Traffic Models and Quality Evaluation Methods for Media and XR Services in 5G Systems", and concluded the QoS requirements in terms of delay budget, data rate and error rate necessary for a satisfactory experience at the application level. These led to 4 additional 5QIs for the 5GS XR QoS

flows as delay-critical GBR 5Qis valued 87-90. These are described at 3GPP Technical Specification TS 23.501 (v18.1.0 – April 2023) titled “System architecture for the 5G System (5GS)” and in particular Table 5.7.4-1. The latter are applicable to XR video streams and control metadata necessary to provide immersive and interactive XR experiences.

[0065] XR video traffic is mainly composed of multiple DL/UL video streams of high resolution (e.g., at least 1080p dual-eye buffer usually), frames-per-second (e.g., 60+ fps) and high bandwidth (e.g., usually at least 20-30 Mbps) which needs to be transmitted across a network with minimal delay (typically upper bounded by 15-20 ms) to maintain a reduced end-to-end application round-trip interaction delay. The latter requirements are of critical importance given the XR application dependency on cloud/edge processing (e.g., content downloading, viewport generation and configuration, viewport update, viewport rendering, media encoding/transcoding etc.).

[0066] The traffic of immersive and interactive XR applications as the ones described above require often real-time suited transport architectures and protocols. As part of the latter, the state of art is represented by the Real-time Transport Protocol (RTP, as defined in IETF standard RFC 3550 – RTP: A Transport Protocol for Real-Time Applications), its securely provisioned Secure Real-time Transport Protocol (SRTP, as defined in IETF standard RFC 3711 – The Secure Real-time Transport Protocol), and its web-targeted stack Web Real-Time Communications WebRTC (defined by w3.org in WebRTC 1.0: Real-Time Communication Between Browsers), respectively.

[0067] RTP is a media codec agnostic network protocol with application-layer framing used to deliver multimedia (e.g., audio, video etc.) data in real-time over IP networks. It is used in conjunction with a sister protocol for control, i.e., Real-time Transport Control Protocol (RTCP), to provide end-to-end features such as jitter compensation, packet loss and out-of-order delivery detection, synchronization, and source streams multiplexing.

[0068] Figure 4 provides an overview of the RTP and RTCP stack. An IP layer 405 carries signaling from the data plane 410 and from the control plane 450. The data plane 410 stack comprises functions for a User Datagram Protocol (UDP) 412, RTP 416, RTCP 414, Media codecs 420 and quality control 422. The control plane 450 stack comprises functions for UDP 452, Transmission Control Protocol (TCP) 454, Session Initiation Protocol (SIP) 462 and Session Description Protocol (SDP) 464.

[0069] SRTP is a secured version of RTP, and is defined by the IETF in RFC 3711 “The Secure Real-time Transport Protocol (SRTP)”. SRTP provides encryption (mainly by

means of payload confidentiality), message authentication and integrity protection (by means of PDU, i.e., headers and payload, signing), as well as replay attack protection. Similarly to RTP, the SRTP sister protocol is SRTCP. This provides the same functions to its RTCP counterpart. As such, in vanilla SRTP versions, the RTP header information is still accessible but non-modifiable, whereas the payload is encrypted. These security provisions are illustrated in part over the right-hand side of Figure 3. Furthermore, the key exchange and additional security parameters necessary to use SRTP are based upon the Datagram Transport Layer Security (DTLS) key exchange procedure. SRTP is used for these reasons as the transport protocol for media in the WebRTC stack which ensures secure RTC multimedia communications over web browser interfaces.

[0070] Figure 5 illustrates an overview of the WebRTC stack. As illustrated, an IP layer 505 carries signaling from the data plane 510 and the control plane 550. The data plane stack 510 comprises functions for User Datagram Protocol (UDP) 512, Interactive Connectivity Establishment (ICE) 524, Datagram Transport Layer Security (DTLS) 526, SRTP 517, SRTCP 515, media codecs 520, Quality Control 522 and SCTP 528. ICE 524 may use the Session Traversal Utilities for NAT (STUN) protocol and Traversal Using Relays around NAT (TURN) to address real-time media content delivery across heterogeneous networks and NAT rules and firewalls. The SCTP data plane 728 is mainly dedicated as an application data channel and may be non-time critical. The SRTP based stack 517 and elements of control, i.e., SRTCP 515, encoding, i.e., media codecs, and Quality of Service (QoS), i.e., Quality Control, are dedicated to time-critical transport. The control plane 550 stack comprises functions for Transmission Control Protocol (TCP) 554, Transport Layer Security (TLS) 556, Hypertext Transfer Protocol (HTTP) 558, WebSocket 566, Session Initiation Protocol (SIP) 562, Session Description Protocol (SDP) 564, Server-sent Events (SSE) 568 and Extensible Messaging and Presence Protocol (XMPP) 570.

[0071] Figure 6a illustrates a packet format and header information for an RTP packet 630 and Figure 6b illustrates a packet format and header information for an SRTP packet 660. The individual fixed header information and complete header information (including header extensions) is briefly summarized for the RTP/SRTP packets as follows.

[0072] Fixed Header Info comprises “V” 632, 662, “P” 633, 663, “X” 634, 664, “CC” 636, 666, “M” 638, 668, “PT” 640, 670, “Sequence number” 642, 672, “Timestamp” 644,

674, “Synchronization Source (SSRC) identifier” 646, 676, and “Contributing Source (CSRC) identifier” 648, 678.

[0073] “V” 632, 662 is 2 bits indicating the protocol version used.

5 [0074] “P” 633, 663 is a 1 bit field indicating that one or more zero-padded octets at the end of the payload are present, whereby, among others, the padding may be necessary for fixed-sized encrypted blocks or for carrying multiple RTP/SRTP packets over lower layer protocols.

[0075] “X” 634, 664 is a 1 bit indicating that the standard fixed RTP/SRTP header will be followed by an RTP header extension usually associated with a particular data/profile
10 that will carry more information about the data (e.g., the frame marking RTP header extension for video data (as defined in IETF RFC 3711 – The Secure Real-time Transport Protocol (SRTP)), or generic RTP header extensions such as the RTP/SRTP extended protocol (as defined by w3.org in WebRTC 1.0: Real-Time Communication Between Browsers)).

15 [0076] “CC” 636, 666 is a 4 bit field indicating number of contributing media sources (CSRC) that follow the fixed header

[0077] “M” 638, 668 is 1 bit intended to mark an information frame boundary in the packet stream, whose behavior is exactly specified by RTP profiles (e.g., H.264, H.265, H.266, AV1 etc.)

20 [0078] “PT” 640, 670 is 7 bits indicating the payload type, which in case of video profiles is dynamic and negotiated by means of SDP (e.g., 96 for H.264, 97 for H.265, 98 for AV1 etc.)

[0079] “Sequence number” 642, 672 is 16 bits indicating the sequence number which increments by one with each RTP data packet sent over a session.

25 [0080] “Timestamp” 644, 674 is 32 bits indicating timestamp in ticks of the payload type clock reflecting the sampling instant of the first octet of the RTP data packet (associated for video stream with a video frame), whereas the first timestamp of the first RTP packet is selected at random.

[0081] “Synchronization Source (SSRC) identifier” 646, 676 is a 32 bit field indicating a
30 random identifier for the source of a stream of RTP packets forming a part of the same timing and sequence number space, such that a receiver may group packets based on synchronization source for playback.

[0082] “Contributing Source (CSRC) identifier” 648, 678 is a list of up to 16 CSRC items of 32 bits each given the amount of CSRC mixed by RTP mixers within the current

payload as signaled by the CC bits; the list identifies the contributing sources for the payload contained in this packet given the SSRC identifiers of the contributing sources.

[0083] Complete Header Information (incl. header extensions) comprises “RTP header extension” 648, 678.

5 [0084] “RTP header extension” 648, 678 is a variable length field present if the X bit is marked; the header extension is appended to the RTP fixed header information after the CSRC list if present; the RTP header extension is 32-bit aligned and formed of the following fields:

- A 16-bit extension identifier defined by a profile and usually negotiated and
10 determined via the Session Description Protocol (SDP) signaling mechanism;
- A 16-bit length field describing the extension header length in 32-bits multiples excluding the first 32 bits corresponding to the 16 bits extension identifier and the 16 bits length fields itself; and
- A 32-bit aligned header extension raw data field formatted according to some
15 RTP header extension identifier specified format.

[0085] Figure 7 illustrates RTP/SRTP header extension format and syntax 700. The RTP header extension format and syntax are like the ones of SRTP. A sketch of these is thus commonly provided as shown in Figure 7. In addition, in both RTP and SRTP only one RTP extension header may be appended to the fixed header information, as defined
20 in IETF RFC 3550 - RTP: A Transport Protocol for Real-Time Applications. However, for both RTP and SRTP extensions to the base protocols exist to allow for multiple RTP header extensions of predetermined types to be appended to the fixed header information of the protocols, as per RFC 8285: A General Mechanism for RTP Header Extensions (rfc-editor.org).

25 [0086] In some embodiments, RTP header extensions produced at the source may be ignored by the destination endpoints that do not have the knowledge to interpret and process the RTP header extensions transmitted by the source endpoint.

[0087] The study of XR Media (XRM) at the CN level in Release 18 of the 3GPP technical standards introduced the concept of a PDU Set to handle QoS requirements of
30 XRM applications and streams with a better granularity beyond QoS flow possibilities. As such, according to 3GPP Technical Report TR 23.700-60 (v0.0.3), a PDU Set is composed of one or more PDUs carrying the payload of one unit of information generated at the application level (e.g. a frame or video slice for XRM Services). In some implementations all PDUs in a PDU Set are needed by the application layer to use the

corresponding unit of information. In other implementations, the application layer can still recover parts or all of the information unit, when some PDUs are missing.

[0088] In addition, the PDU Set is associated with QoS requirements in terms of delay budget and error rate, which may be defined as PDU Set Delay Budget (PSDB), and/or
5 as a PDU Set Error Rate (PSER) as defined in 3GPP Technical Report TR 23.700-60 (v0.0.3 – May 2022) titled “Study on XR (Extended Reality) and media services” and 3GPP Technical Specification TS 23.501 (v18.1.0 – April 2023) titled “System architecture for the 5G System (5GS)”. The PDU Set Delay Budget (PSDB) defines an upper bound for the time that a PDU-Set may be delayed between the UE and the N6
10 termination point at the UPF. PSDB applies to the DL PDU-Set received by the UPF over the N6 interface, and to the UL PDU-Set sent by the UE, and respectively. The PDU Set Error Rate (PSER) defines an upper bound for the rate of PDU-Sets (e.g. set of IP packets constituting a PDU-Set) that have been processed by the sender of a link layer protocol (e.g. RLC in RAN of a 3GPP access). The PSER may be used to determine an
15 upper bound for a rate of non-congestion-related packet losses.

[0089] Figure 8 illustrates an overview of a core network (CN) XRM architecture handling of PDU Sets. Figure 8 shows a system 800 comprising an Extended Reality Media Application Function (XRM AF) 810, a Policy and Control Function (PCF) 815, a Session Management Function (SMF) 820, an Access and Mobility Function (AMF) 825,
20 a Radio Access Network (RAN) 830, a User Equipment (UE) 835, a User Plane Function (UPF) 840, and an Extended Reality Application 845. The UE 835 may comprise a remote unit 102, a user equipment apparatus 200, a UE, 1035 or 1135 as described herein. The UPF 840 may comprise a network unit 104, a network node 300, or a User Plane Function (UPF) as described herein such as UPF 1040 and 1140. The operation of
25 system 800 will now be described in the example of downlink traffic, a similar process may operate for uplink traffic.

[0090] At 880, the XRM AF 810 determines PDU-set requirements.

[0091] At 881, the XRM Application Function 810 provides QoS requirements for packets of a PDU Set to the PCF 815 and information to identify the application (i.e. 5-tuple or application id). The QoS requirements may comprise PSDB and PSER. The
30 XRM AF 810 may also include an importance parameter for a PDU Set and information for the core network to identify packets belonging to a PDU Set.

[0092] At 882, the PCF 815 derives QoS rules for the XR application and specific QoS requirements for the PDU Set and configures the SMF 820. The QoS rules may use a

5G QoS identifier (5QI) for XR media traffic. The PCF 815 sends the QoS rules to the SMF 820. The PCF 815 may include in the communication to the SMF 820 PCC rules per importance of a PDU Set. The PCC rules may be derived according to information received from the XRM AF 810 or based on an operator configuration.

5 [0093] At 883, the SMF 820 establishes a QoS flow according to the QoS rules by the PCF 815 and configures the UPF to route packets of the XR application to a QoS flow, and, in addition, to enable PDU Set handling. The SMF 820 also provides the QoS profile containing PDU Set QoS requirements to the RAN 830 via the AMF 825. The AMF 825 may provide the QoS profile containing PDU Set QoS requirements to the
10 RAN 830 in an N2 SM container. Further, the AMF 825 may provide the QoS rules to the UE 835 in an N1 SM container.

[0094] At 884, the UPF 840 inspects the packets and determines packets belonging to a PDU Set. The packet inspection may comprise inspecting the RTP packets. When the UPF 840 detects packets of a PDU Set the UPF 840 marks the packets belonging to a
15 PDU Set within a GTP-U header. The GTP-U header information includes a PDU Set sequence number and the size of the PDU Set. The UPF 840 may also determine the importance of the PDU Set either based on UPF 840 implementation means, information provided by the XRM AF 810 or information provided as metadata from an XRM application server. Based on the importance of the PDU Set the UPF 840 may
20 route the traffic to a corresponding QoS flow 1 (according to the rules received from the SMF 820) or include the importance of the PDU Set within a GTP-U header. QoS flow 1 may comprise GTP-U headers, and these may include PDU Set information.

[0095] At 885, the RAN 830 identifies packets belonging to a PDU Set (based on the GTP-U marking) and handles the packets of the PDU-set according to the QoS
25 requirements of the PDU Set provided by the SMF 820. In one implementation the RAN 830 node may use a different radio bearer with higher QoS requirement (according to the PDU Set PSDB/PSER) to guarantee delivery of the packets of the PDU-set, while using a different radio bearer according to the 5QI of the QoS flow for the non-PDU-set packets. RAN 830 may receive QFIs, QoS profile of QoS flow from SMF 820 (via AMF
30 825) during PDU session establishment/modification which includes PSDB and PSER. RAN 830 inspects GTP-U headers and ensures all packets of the same PDU Set are handled according to the QoS profile. This may include packets of PDU-set in a radio bearer carrying QoS flow 1. This may also include sending packets not belonging to the PDU-set in a different radio bearer carrying QoS flow 2.

[0096] The above example relates to downlink (DL) traffic. Reciprocal processing is applicable to uplink (UL) traffic wherein the role of UPF 840 packet inspection is taken by the UE 835 which is expected to inspect uplink packets, determine packets belonging to a PDU Set, and signal accordingly the PDU Set to the RAN 830 for scheduling and resource allocation corresponding to an associated DRB fulfilling capable of fulfilling the PDU Set QoS requirements (i.e., PSDB and PSER). The low-level signaling mechanism associated with the UL UE-to-RAN information passing are up to the specification and implementations of RAN signaling procedures.

[0097] Figures 9a to 9d illustrate 5GS PDU Set-aware QoS handling framework description of PDU Set to QoS flow to DRB mappings. Depending on the QoS flow mappings and RAN procedures, several alternative PDU Set to QoS flow to DRB mappings are possible given two distinct PDU Sets with different PDU Set attributes, such as PDU Set importance. Figure 9 illustrates some options where two PDU Sets of different importance and characteristics are mapped to QoS flows and respectively to Data Radio Bearers (DRBs). Consider in this example PDU Set 1 to be of high importance with strict QoS requirements (i.e., PSDB, PSER etc.) and PDU Set 2 to be of low importance with potentially lower QoS requirements (i.e., PSDB, PSER etc.) than PDU Set 1. As illustrated in Figure 9, the mapping of PDU Set 1 to QoS flow 920 to DRB 930 can take the following instantiations depending on QoS flow policies and Layer 2 RAN procedures:

[0098] Figure 9a illustrates 1-to-1-to-1 mapping: whereby the separation of QoS flows 920 and DRBs 930 is complete between high and low importance PDU Sets 910 optimizing finely the radio and network resources on a per PDU Set basis.

[0099] Figure 9b illustrates M-to-M-to-1 mapping: whereby the separation between high and low importance PDU Sets 910 is performed only at QoS flow level, whereas the same DRB 930 is used for the over-the-air transmission of both PDU Sets 910, which may lead to overprovisioning of radio resources for low importance PDU Sets 910 yet require a lower overhead of RAN complexity and management.

[0100] Figure 9c illustrates M-to-1-to-1 mapping: whereby there is no separation between the QoS flows 920 and DRBs 930 of different importance PDU Sets 910 and the higher importance PDU Set QoS requirements are prioritized in handling the QoS management across both CN and RAN; this may lead to overprovisioning of resources for low importance PDU Sets 910 in both CN and RAN implementations but requires lower overhead and control within the 5GS QoS framework.

[0101] Figure 9d illustrates M-to-1-to-M mapping; whereby there is no separation across the QoS flows 920 between PDU Set importance levels, yet distinct DRBs 930 are used to cater for the individual requirements of the distinct importance levels; this compromises the QoS flow management complexity and uses PDU Set information to
5 filter the PDU Sets 910 on different DRBs 930 in order to better match the QoS requirements at RAN level and optimize resource allocation according to individual PDU Set needs.

[0102] In addition, RAN Layer 2 procedures may use the PDU Set importance attribute and associated information for prioritization of PDU Sets. In one instance the
10 prioritization strategy may take the form of dropping PDU Sets of lower importance in the presence of RAN congestion. In other instances, the RAN may use alternative prioritization strategies in resource allocation as required per different gNB implementations, whereby the PDU Set importance information is leveraged to determine the resource allocation strategy for PDU Sets of varying importance.

[0103] The determination of PDU Sets is a prerequisite to control the PDU Set flow
15 through the 5GS and implicitly to control the QoS flow to DRB mapping within the QoS 5GS framework. Therefore, to support PDU Set based QoS handling, the PDU session anchor (PSA) UPF identifies PDUs that belong to PDU Sets and determines the PDU Set Information which it sends to the NG-RAN in the GTP-U header. The PDU
20 Set information is used by the NG-RAN for PDU Set based QoS handling as described above.

[0104] The PDU Set Information comprises some combination of:

- PDU Set Sequence Number (PSSN).
- Indication of End PDU (E) of the PDU Set
- 25 • PDU Sequence Number (PSN) within a PDU Set
- PDU Set Size (PSSize) in bytes.
- PDU Set Importance (PSI), which identifies the relative importance of a PDU Set compared to other PDU Sets within a QoS Flow.
- End of Data Burst (EDB) information, marking the end of a data burst, whereby
30 a data burst is a set of multiple PDUs generated and sent by the application such that there is an idle (i.e., silent, pause, or alternatively non-active) period between two data bursts. Consequently, a Data Burst may be composed of one or multiple PDU Sets.

[0105] The RAN lower layers can further make use of the PDU Set Importance marked within a QoS Flow for PDU Set level packet discarding in presence of congestion over the radio air interface. Furthermore, the interrelation between PSI across multiple QoS flows may be considered.

5 [0106] The SMF instructs the PSA UPF to perform PDU Set marking and may provide the PSA UPF the Protocol Description served over a 5 tuple (i.e., a tuple formed of source IP address, destination IP address, source port, destination port, and protocol number) or an application ID (i.e., an identifier of one or more AF sessions associated with an application) indicating the header, extension header (e.g., RTP/SRTP) and
10 payload type (e.g. H.264) used by the service data flow. The Protocol Description may be received in the PCC rule, based on information provided by the AF or by PCF local policies.

[0107] Consequently, the PSA UPF can identify the PDU Set information by using the Protocol Description and the received RTP/SRTP headers, as indicated by a UPF, (as
15 for example described in United States provisional patent application 63/428,026, filed 25 November 2022 [Applicants ref: SMM920220198-US-PSP] , incorporated herein by reference) over an RTP header extension for PDU Set information. Alternatively, the PSA UPF can identify the PDU Set information by using UPF implementation specific means, (as for example described in PCT application PCT/EP2022/077327 filed on 30
20 September 2022 [Applicants ref: SMM920220109-GR-NP], incorporated herein by reference) whereby at least the RTP/SRTP timestamp, synchronization source identifier and M-bit end of frame marker are utilized to determine the boundaries of a PDU Set, and the PDU Set size is utilized to determine the PDU Set importance based on the available application traffic and codec configuration information. As a result, for each
25 DL PDU received on N6 for which PDU Set based QoS handling is indicated from the SMF, the PSA UPF applies the rules for PDU Set identification and provides PDU Set information which is available to the RAN in the GTP-U header.

[0108] In some implementations, a 5GS comprises the PDU Set marking by the AS and its associated information, as previously detailed, in RTP header extensions according to
30 the IETF RFC 8285. This can be either in one-byte or two-byte formats as displayed in Figures 10a and Figure 10b.

[0109] Figure 10a illustrates an example of a one-byte RTP Header Extension 1000 for the marking of PDU Set information. Figure 10b illustrates an example of a two-byte RTP Header Extension 1050 for the marking of PDU Set information.

[0110] The semantics associated with the PDU Set information fields of the RTP header extension syntaxes outlined in Figure 10a and Figure 10b are as follows.

[0111] “E” 1032 is a 1 bit representation of a Boolean flag that shall be set to 1 for the last PDU of the PDU Set and set to 0 for all other PDUs of the PDU Set.

5 [0112] “EDB” 1034 is a 3 bit representation of the end of a Data Burst indication. The 3 bits may encode for example the End of Data Burst indication as per the encoding and guidelines provided in Clause 4.4.2.6.1 of the 3GPP Technical Specification TS 26.522 titled “5G Real-time Media Transport Protocol Configurations”.

[0113] “PSI” 1036 is a 4 bit representation indicating the importance of a PDU Set
10 compared to other PDU Sets within the same RTP stream, or alternatively, session. Lower values shall indicate a higher importance PDU Set, with the highest importance PDU Set indicated by 0 and the lowest importance PDU Set indicated by 15. This field is applicable for various audio/video codecs supported by a 5GS (e.g., H.264, H.265, HE-AAC etc.).

15 [0114] “PSSN” 1040 comprises a 10 bit representation encoding the sequence number of the PDU Set to which the current PDU belongs acting as a 10-bit numerical identifier for the PDU Set. PSSN may take a value between 0 and 1023, and even though the value may wrap around 1023 in some examples, a receiver (e.g., UPF) may uniquely distinguish between any PDU Sets using a combination of the RTP packet sequence number and the
20 PSSN.

[0115] “PSN” 1042 is a 6 bit representation of the sequence number of the current PDU within the PDU Set. The PSN shall be set to 0 for the first PDU in the PDU Set and incremented monotonically for every PDU in the PDU Set in order of transmission from the sender. A receiver (e.g., UPF, or alternatively, in some examples a gNB) may use the
25 RTP packet sequence number together with the PSN to distinguish between PDUs within a PDU Set that contains more than 64 PDUs.

[0116] “PSSize” 1044 is a 24 bit representation indicating the total size of all PDUs of the PDU Set to which this PDU belongs. This field is optional and subject to an SDP signaling offer/answer negotiation, where the AS may indicate whether it will be able to
30 provide the size of the PDU Set for an RTP stream, or alternatively, an RTP session. If in some embodiments it is not enabled, the field will not be present. However, if in some embodiments is enabled, but the AS is not able to determine the PDU Size for a particular PDU Set, the AS will set the value to 0 in all PDUs of that PDU Set. The PSSize indicates in some implementations the size of a PDU Set including

RTP/UDP/IP header encapsulation overhead of its corresponding PDUs. Alternatively, the PSSize indicates the sum of RTP payload sizes of all PDUs present in a PDU Set. The PSSize is expressed in bytes. As this field is optionally appended to the RTP header extensions, its presence is negotiated and signaled via SDP offer/answer procedure by means of the “pdu-set-size” extension attribute, as per example:

```
...
a=extmap:1 sendonly urn:3gpp:pdu-set-marking:rel-18 pdu-set-size
...
```

[0117] However, the currently defined architecture lacks some technical details necessary to resolve QoS flows that must transport both PDU Set marked and non-PDU Set marked traffic. There are a couple of scenarios possible: Scenario #1 (Different AF sessions) is illustrated in Figure 11; and Scenario #2 (Same AF session) is illustrated in Figure 12.

[0118] Scenario #1 comprises Different AF sessions. A QoS Flow that is established with a PDU Set QoS parameters configuration (e.g., by means of Nnef_AFsessionWithQoS service) may also satisfy the QoS requirements of another AF session (either belonging to the same XR application or not) with similar PDB and PER as that of the PDUs enclosed in the PDU Sets. In such a case, an operator’s general policies and PCC rules may assign the PDU Set marked and non-PDU Set marked PDUs on the same QoS Flow.

[0119] Figure 11 illustrates an example of a scenario comprising different AF sessions for an XR video application and a non-XR application being multiplexed by a 5GS under the current PCF policies and PCC rules over the same QoS Flow, i.e., QoS Flow 1 that satisfies both the PSDB and PSER requirements of the PDU Set marked XR service traffic, and the PDB and PER of the non-PDU Set marked non-XR service traffic.

[0120] Figure 11 illustrates a scenario #1 representing two different AF sessions combining PDU Set marked and non-PDU Set marked PDUs over a QoS flow with the same QoS parameters. The illustrated system 1100 comprises a PCF 1115 an SMF 1120, a UPF 1140, a RAN 1130, a UE 1135, an XR video application 1145, and a non-XR video application 1147. The UE 1135 may comprise a remote unit 102, a user equipment apparatus 200, a UE 835 or 1235 as described herein. The UPF 1140 may comprise a network unit 104, a network node 300, or a User Plane Function (UPF) as described herein such as UPF 840 and 1240. The XR video application 1145 transmits an I-frame as a plurality of PDUs, the PDUs grouped to form a PDU Set. The XR video application 1145 also transmits a P-frame as a plurality of PDUs, those PDUs also

grouped to form a PDU Set. The non-XR application 1147 transmits other data as a plurality of PDUs, the PDUs grouped to form a further PDU Set. The UPF 1140 is arranged to receive PDUs from both the XR video application 1145, and the non-XR video application 1147 and transmit PDUs to the RAN 1130 a QoS flow having PDSB/PSEER requirements. The UPF 1140 includes PDU Set information with PDUs from the XR video application 1145. The UPF 1140 does not include PDU Set information with PDUs from the non-XR application 1147. The RAN 1130 transmits PDUs to the UE 1135 via a Uu radio bearer.

[0121] Scenario #2 comprises the Same AF sessions. A QoS Flow that is established with a PDU Set QoS parameters configuration (e.g., by means of Nnef_AFsessionWithQoS service) may be exposed to both PDU Set and non-PDU Set marked traffic. This can happen for instance in case of WebRTC services whereby multiple media streams are multiplexed over a single RTP stream served over one AF session instance. Alternatively, this can also happen for media streams belonging to the same XR application (i.e., sharing the application ID) which are mapped given their 5 tuples and QoS requirements to the same QoS Flow. For example, multiple cameras capturing systems, e.g., as for 360 degrees surround video, or alternatively, at least two cameras for 2D+depth video information, may be used concurrently over different RTP streams. In any of these examples, a use case that is common is that at least one of the media streams does not contain PDU Set marking. In an example this may be since the PDU Set may not support a particular video codec specification (e.g., VP8, VP9, AV1), a particular audio codec specification (e.g., OPUS), a particular multimedia codec specification (e.g., tactile codecs), or alternatively, any multimedia codec specification except video (e.g., audio codecs, tactile codecs etc.).

[0122] Figure 12 illustrates an example scenario comprising the same AF sessions for an XR application served over WebRTC where the audio (e.g., OPUS encoded bitstream) and the video (e.g., H.264 constrained baseline encoded bitstream) are transmitted in multiplex over one RTP stream for an XR application.

[0123] Figure 12 illustrates a scenario #2 representing one AF session multiplexing PDU Set marked and non-PDU Set marked PDUs over a QoS flow with the same QoS parameters. The illustrated system 1200 comprises a PCF 1215 an SMF 1220, a UPF 1240, a RAN 1230, a UE 1235, and an XR video application 1245. The XR video application 1245 comprises a WebRTC App. The UE 1235 may comprise a remote unit 102, a user equipment apparatus 200, a UE 835 or 1135 as described herein. The UPF

1240 may comprise a network unit 104, a network node 300, or a User Plane Function (UPF) as described herein such as UPF 840 and 1140. The XR video application 1245 transmits an I-frame as a plurality of PDUs, the PDUs grouped to form a PDU Set. The XR video application 1245 also transmits a P-frame as a plurality of PDUs, those PDUs also grouped to form a PDU Set. The XR application 1245 further transmits non-video frame information as a plurality of PDUs, the PDUs grouped to form a yet further PDU Set. The non-video frame information may comprise audio OPUS codec and/or AR metadata non-marked with PDU Set info, for example. The UPF 1240 is arranged to receive PDUs from the XR video application 1245 and to transmit PDUs to the RAN 1230 a QoS flow having PDSB/PSER requirements. The UPF 1240 includes PDU Set information with PDUs from the XR video application 1245 that comprise video information. The UPF 1240 does not include PDU Set information with PDUs from the XR video application 1245 that relate to non-video frame information. The RAN 1230 transmits PDUs to the UE 1235 via a Uu radio bearer.

[0124] The two scenarios described above with reference to Figures 11 and 12 indicate that on a DRB mapped to a QoS Flow enabled with the PDU Set feature for an XR application, the RAN may receive packets mixed, i.e., some of which are marked with the PDU Set information and some of which are not marked with the PDU Set information. The packets (which are PDUs) not marked with PDU Set information may be referred to as “legacy packets”. These legacy packets are nonetheless handled under the same QoS characteristics of the QoS Flow (i.e., PSDB, PSER, PER and respectively PDB at a minimum). As a result, the RAN complexity is increased as different handling and scheduling of radio resources is necessary for packets belonging on the same QoS Flow.

[0125] Furthermore, the 3GPP RAN has decided to eliminate such complexity in the 5GS at lower layers by taking out of scope of further normative specification the mapping M-1-M illustrated in Figure 9d, whereby the packets of a QoS Flow are split over multiple DRBs. The different treatment at the radio level of packets on the same QoS Flow is thus not currently possible. As such, the QoS policies and PDU Set marking features within 5GS need to further alleviate this while maintaining a lower complexity at the RAN level and attain a good complexity-performance trade-off at the system level.

[0126] Nevertheless, particularly for Scenario #2, the importance value of UPF marked PDU Sets is of critical relevance to the 5GS. This value needs to be determined relative to the AS marked PDU Sets that are mapped to the same QoS Flow for the AF Session. As such, the importance values need alignment across the multiplexed data flows for a

correlated and coherent treatment by the gNB and RAN Layer 2 procedures of all PDU Sets belonging to the different RTP multiplexed media streams, or alternatively, data sessions.

[0127] There are presented herein methods and apparatuses that tend to address the
5 above issue by introducing the concept of a common, default importance value for a QoS Flow containing one or more multiple data flows, or alternatively, RTP streams as part of an AF session.

[0128] There are described herein methods and apparatuses that provide a uniform treatment of PSI for PDU Sets originating from one or more data flows multiplexed over
10 a common AF session mapped to a QoS Flow with common PDU Set QoS requirements, i.e., PDU Set Delay Budget (PSDB), PDU Set Error Rate (PSER) and PDU Set Integrated Handling Indicator (PSIHI) as described in clause 5.7.7 of 3GPP TS 23.501 (v18.1.0 – April 2023) titled “System architecture for the 5G System (5GS)”. To this end, a default PSI value is defined. The default PSI is applied by the UPF in marking
15 any unmarked PDUs of the AF Session with PDU Set information.

[0129] The default PSI value may be statically and implicitly determined per QoS Flow with PDU Set requirements. The default PSI value may be semi-statically determined and signaled by the AF to the 5GS. Further, this value may be common to a plurality of data flows multiplexed under the AF session; alternatively, each of the data flows may have a
20 default importance value based on a protocol description.

[0130] The UPF may use the default PSI value to mark unmarked PDUs of the AF Session with PDU Set information, including the PSI field which is marked with the default PSI value.

[0131] A default PSI value for a QoS flow with PDU Set requirements is described
25 herein. In one example, the UPF receives N4 rules from the SMF. The N4 rules include information to assist the UPF to identify how a packet received in the downlink direction needs to be routed over an established QoS flow and whether PDU Set information is needed to be added for any packet sent over a QoS flow that has specific PDU Set QoS requirements.

[0132] The SMF determines N4 rules based on a PCC rule provided by the PCF. The PCF determines PCC rules based on the PDU Set QoS requirements of an application user plane session to a UE via the 3GPP network (i.e., an AF session). The PDU Set QoS requirements are provided in some embodiments by an Application Function (AF)

interfacing with the PCF, e.g., over N5 interface and APIs, or alternatively, with the NEF, e.g., over N33 interface and APIs.

[0133] By way of example, the AF session PDU Set QoS requirements can include PSDB, PSER, and PSIH parameters. In addition, the AF provides a Protocol

5 Description. The Protocol Description indicates in some embodiments at least protocol attribute (e.g., RTP/SRTP) and a payload type attribute (e.g., H.264, H.265) of the AF session. The Protocol Description used by the service data flow indicates therefore in some embodiments to the UPF via the derived PCC rules and associated N4 SMF rules the needs to support specific PDU Set QoS requirements over the 3GPP network.

10 [0134] In embodiments where the UPF receives packets in the downlink direction (e.g., over N6 reference point), the UPF checks in return if each packet matches any of the N4 rules provided by the PCF/SMF for the established AF Session with the UE. In some embodiments, the UPF determines that for a received packet in the downlink direction PDU Set inspection needs to be performed as indicated by the N4 rules. In some
15 embodiments, the PSA UPF can identify the PDU Set information using the Protocol Description and the received RTP/SRTP headers extension elements corresponding to PDU Set marking by the AS, or alternatively, using UPF implementation specific means of deriving the PDU Set marking. The UPF may thus determine and add at least one or more of the following information fields within a GTP-U header of a packet when the
20 packet is sent to the NG-RAN over a QoS flow with QoS PDU Set requirements:

- the PSSN field indication as PDU Set Sequence Number;
- the E field indication as indication of End PDU of the PDU Set;
- the PSN field indication as PDU Sequence Number within a PDU Set;
- the PSSize field indication as PDU Set Size in bytes;
- 25 • the PSI field indication as PDU Set Importance, which identifies the relative importance of a PDU Set compared to other PDU Sets within the same QoS Flow; and
- the EDB field indication, which signals the end of a data burst.

[0135] If the packet received in the downlink direction matches the Protocol

30 Description in the N4 rule then there are two additional options that may be considered:

[0136] Option 1: the received packet may not have any additional RTP header extension which include PDU Set information. The UPF may determine in such an embodiment the PDU Set information based on its implementation.

- [0137] Option 2: some of the received packets may include RTP header extension elements comprising PDU Set marking and PDU Set information provided by the AS. In this case, the UPF must include (e.g., by performing a 1:1 mapping, or alternatively, a copy) the information contained within the RTP header extensions to the corresponding PDU Set information within the GTP-U header of the PDUs forming the PDU Sets. Alternatively, if some of the received packets do not have any PDU Set information within RTP header extensions, the UPF will include for each packet (i.e., PDU), default PDU Set information by means of PDU Set marking within the GTP-U header when each packet is sent to the NG-RAN.
- [0138] Alternatively still, if the packet received in the downlink direction does not match the Protocol Description in the N4 rule, but the N4 rule includes an indication to perform PDU Set inspection then for each received packet (i.e., PDU over N6 interface) that does not match the protocol description, the UPF will map such a packet to a PDU Set and include default PDU Set information within GTP-U header when the packet is sent to the NG-RAN. As such, the UPF will ensure that over a QoS flow with PDU Set QoS requirements all PDUs are belonging to a PDU Set. Furthermore, the PDU Set comprising a single PDU as result of UPF default PDU Set marking may comprise a PDU-set size corresponding to the size of the single received packet, or alternatively, PDU over N6 interface.
- [0139] In one example, the default UPF marking of AS-unmarked PDUs with PDU Set information comprises of at least one of:
- an auto generated PSSN (e.g., by an unit increment of the last observed PSSN corresponding to the service data flow of the AF session) based on the UPF determined sequence of past identified PSSNs;
 - a default '0'-valued PSN for the PDU comprising the PDU Set;
 - a default '1'-valued, or alternatively, marked encoding, of the E field indicating the end PDU of the PDU Set;
 - a default PSSize instantiated by the size in bytes of the PDU (including the transport protocol overheads, e.g., RTP/UDP/IP) contained in the PDU Set;
 - a default marking of the EDB field by the UPF based on the PCC and N4 rules, i.e., in some examples where C-DRX enhancement support is disabled, the EDB field is left unmarked, e.g., as '000', or equivalent, and not used in the 5GS; and
 - a default PSI value determined by the UPF.

[0140] The default PSI value determined by the UPF may be determined according to any one of three strategies:

- In a first strategy, the default PSI is determined statically by the PCF given a mobile network operator set of service level agreement policies associated with an AF request for a QoS Flow with PDU Set QoS requirements. In such scenarios, the AF may not need to provide further indication of preferred default PSI values.
- In a second strategy the default PSI value is configured based on the AF indication and request to provision a QoS Flow with PDU Set requirements. The default PSI value is comprised within the PCC and N4 rules generated by the PCF and SMF based on the AF request to provision a service data flow session over the 5GS. As such, the AF requests an AF session creation with QoS PDU Set parameters, comprising further protocol parameters for the provisioning and determination of the QoS Flow configuration by the 5GS.
- In a third strategy the default PSI is determined based on configuration at UPF. The configuration may be sent via Operations, Administration and Management (OAM) procedures.

[0141] The AF request for a QoS Flow with PDU Set QoS requirements can additionally comprise session attributes describing at least:

- a protocol identifier for the service data flow (e.g., an RTP session multiplexing one or more RTP media streams, or alternatively, one or more RTP media streams and RTCP data flows);
- a payload type identifier, or alternatively, a subprotocol or a subservice data flow identifier (e.g., an RTP payload identifier such as H.264 = 96, H.265 = 97, OPUS = 112, RTCP message types based on RFC 3550 and RFC 5761, or alternatively, RFC 8858 etc.);
- and a default PSI value (e.g., default PSI = 8 for a PSI scale of 0 as highest importance and 15 as lowest importance, or, default PSI = 15 for a PSI scale of 0 as highest importance and 15 as lowest importance, or alternatively, default PSI = 0 for a PSI scale of 0 as highest importance and 15 as lowest importance).

[0142] The AF request for a QoS Flow with PDU Set QoS parameters may comprise common session parameters for all multiplexed media components, media subcomponents, RTP media streams, or alternatively, service data flow subcomponents

(e.g., RTCP). In one example, the AF would therefore indicate a common default PSI value to the PCF applicable to all media subcomponents.

[0143] In other embodiments, the AF request for a QoS Flow with PDU Set QoS parameters may comprise individual session parameters for each multiplexed media components, media subcomponents, RTP media streams, or alternatively, service data flow subcomponents (e.g., RTCP). In one example, the AF would therefore indicate a common default PSI value of 0 (highest) for an audio media subcomponent, or alternatively, RTP audio stream (e.g., OPUS), a value of 1 (second highest) for a video media subcomponent, or alternatively, RTP video stream (e.g., H.264), and a value of 8 (middle importance) for an RTCP subcomponent of a multiplexed RTP session.

[0144] The AF may combine a common default PSI value request with individual default PSI values for each individual media sub-components of the RTP multiplexed stream session. In such a case, the individual default PSI values would take precedence over the common one, which may act as fallback.

[0145] When the PCF is indicated by the UPF with one or more requested default PSI values, the PCF compares the AF requested default PSI values for a given AF session request. The PCF may determine PCC rules and inform the SMF which in turn determines the N4 rules comprising the one or more default PSI values. In such a case the PCF determined default PSI values may be different than the AF requested ones. This may correspond to the PCF determining for example a lower priority default PSI value instead of a higher priority default PSI value requested by an AF. The PCF may make this determination based at least on one of the protocol descriptions, on the media subcomponents of the multimedia session (e.g., a RTP multiplexed stream comprising marked and unmarked PDUs with PDU Set information), and on a mobile network operator service level agreement and associated policies for charging and handling an XR application's traffic with PDU Set QoS requirements. The SMF N4 rules indicating one or more default PSI values are consequently used by the UPF to mark any unmarked PDUs according as detailed above.

[0146] Accordingly, there is provided a User Plane Function (UPF), comprising a processor and a memory coupled with the processor, the memory comprising instructions executable by the processor to cause the UPF to: receive a configuration, the configuration comprising a protocol description including one or more media stream components and at least one default PDU Set importance value; and receive a protocol data unit (PDU) in a downlink direction wherein the received PDU is subject to PDU Set

processing according to the configuration. The UPF is further caused to determine whether: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set; and to determine a
5 PDU Set importance information value, the determination based on the at least one default PDU Set importance value. The UPF is further caused to create a header for the received PDU, the header including PDU Set information and the determined PDU Set importance information value if either: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description
10 of the received configuration, but the received PDU is not part of a PDU Set; and to route the received PDU and the header to a radio access network.

[0147] The UPF described herein tends to result in improved marking of PDUs in the downlink direction. To ensure proper operation of the radio access network, a QoS Flow enabled with PDU Set marking should have all the PDUs in the downlink direction
15 marked with PDU Set information upon ingestion into the radio access network. Including PDU Set importance information in the marking facilitates differentiation of Quality of Service flows and proper application of Quality of Service requirements in the network. The configuration may be received from a Session Management Function (SMF).

[0148] The PDU and header are routed towards a radio access network together. The radio access network may comprise an NG-RAN. The received PDU may be sent towards the NG-RAN via GTP-U protocol. The header may be a GTP-U header. The received PDU may be sent towards the NG-RAN and the PDU Set information may be included within a GTP-U header of the GTP-U protocol PDU Set information.

25 [0149] The at least one default PDU Set importance value may be configured as either: common to each of one or more media streams components of the protocol description; or individual for each of the one or more media streams components of the protocol description.

[0150] The protocol description may be indicated to a Policy Control Function (PCF) by
30 an Application Function (AF), and the at least one default PDU Set importance value may be requested by the AF for one or more media streams components of an application service data flow.

[0151] The PCF may verify the AF requested default PDU Set importance value and determine the default PDU Set importance value corresponding to the received

configuration based at least on one of: the AF requested default PDU Set importance value; the protocol description and corresponding one or more media components; and a mobile network operator service level agreement and corresponding policies for charging and control of the application service data flow.

5 [0152] The at least one default PDU Set importance value may be determined by the PCF based on a mobile network operator service level agreement. The at least one default PDU Set importance value may be determined by the PCF based on a mobile network operator service level agreement and corresponding policies for charging and control of an application service data flow.

10 [0153] The UPF may be further caused to receive a default PDU Set importance value based on Operations, Administration and Management (OAM) procedures. The OAM policies and procedures may be enforced by a mobile network operator within a public or a private mobile communications network. The procedures may be enforced based on predetermined network operator service level agreements. Alternatively, the
15 procedures may be enforced based on QoS profiles for service data flows enabled with PDU Set processing functionality.

[0154] The UPF may be further arranged to receive the configuration comprising the at least one default PDU Set importance value from a Session Management Function (SMF).

20 [0155] The PDU Set information included in the header may comprise at least one of: a PDU Set Sequence Number (PSSN); an indication of an End PDU (E) of the PDU Set; a PDU Sequence Number (PSN) within the PDU Set; a PDU Set Size (PSSize) in bytes; a PDU Set importance (PSI); and an End of Data Burst (EDB) indication.

[0156] The protocol description may further comprise an indication of at least one of a
25 protocol and a payload type.

[0157] Figure 13 illustrates a method 1300 performed by a User Plane Function (UPF), the method 1300 comprising receiving 1310 a configuration, the configuration comprising a protocol description including one or more media stream components and at least one default PDU Set importance value; and receiving 1320 a protocol data unit
30 (PDU) in a downlink direction wherein the received PDU is subject to PDU Set processing according to the configuration. The method 1300 further comprises determining 1330 whether: the received PDU does not match all components of the received configuration; or the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set; and determining 1340 a

PDU Set importance information value, the determination based on the at least one default PDU Set importance value. The method 1300 further still comprises creating 1350 a header for the received PDU, the header including PDU Set information and the determined PDU Set importance information value if either: the received PDU does not
5 match all components of the received configuration; or the received PDU does match the protocol description of the received configuration, but the received PDU is not part of a PDU Set; and routing 1360 the received PDU and the header to a radio access network.

[0158] In certain embodiments, the method 1300 may be performed by a processor
10 executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0159] The method described herein tends to result in improved marking of PDUs in the downlink direction. To ensure proper operation of the radio access network, a QoS Flow enabled with PDU Set marking should have all the PDUs in the downlink direction
15 marked with PDU Set information upon ingestion into the radio access network. Including PDU Set importance information in the marking facilitates differentiation of Quality of Service flows and proper application of Quality of Service requirements in the network. The configuration may be received from a Session Management Function (SMF).

[0160] The PDU and header are routed towards a radio access network together. The radio access network may comprise an NG-RAN. The received PDU may be sent towards the NG-RAN via GTP-U protocol. The header may be a GTP-U header. The received PDU may be sent towards the NG-RAN and the PDU Set information may be included within a GTP-U header of the GTP-U protocol PDU Set information.

[0161] The at least one default PDU Set importance value may be configured as either: common to each of one or more media streams components of the protocol description; or individual for each of the one or more media streams components of the protocol description.

[0162] The protocol description may be indicated to a Policy Control Function (PCF) by
30 an Application Function (AF), and the at least one default PDU Set importance value may be requested by the AF for one or more media streams components of an application service data flow.

[0163] The PCF may verify the AF requested default PDU Set importance value and determine the default PDU Set importance value corresponding to the received

configuration based at least on one of: the AF requested default PDU Set importance value; the protocol description and corresponding one or more media components; and a mobile network operator service level agreement and corresponding policies for charging and control of the application service data flow.

5 [0164] The at least one default PDU Set importance value may be determined by the PCF based on a mobile network operator service level agreement. The at least one default PDU Set importance value may be determined by the PCF based on a mobile network operator service level agreement and corresponding policies for charging and control of an application service data flow.

10 [0165] The method may further comprise receiving a default PDU Set importance value based on Operations, Administration and Management (OAM) procedures. The OAM policies and procedures may be enforced by a mobile network operator within a public or a private mobile communications network. The procedures may be enforced based on predetermined network operator service level agreements. Alternatively, the
15 procedures may be enforced based on QoS profiles for service data flows enabled with PDU Set processing functionality.

[0166] The method may further comprise receiving the configuration comprising the at least one default PDU Set importance value from a Session Management Function (SMF).

20 [0167] The PDU Set information included in the header may comprise at least one of: a PDU Set Sequence Number (PSSN); an indication of an End PDU (E) of the PDU Set; a PDU Sequence Number (PSN) within the PDU Set; a PDU Set Size (PSSize) in bytes; a PDU Set importance (PSI); and an End of Data Burst (EDB) indication.

[0168] The protocol description may further comprise an indication of at least one of a
25 protocol and a payload type.

[0169] There is further provided an Application Function (AF) comprising a processor and a memory coupled with the processor, the memory comprising instructions executable by the processor to cause the AF to: determine a configuration for a service data flow session for an application server (AS) with PDU Set processing based on at
30 least a protocol description including one or more media streams components and at least one request for a default PDU Set importance value; set the at least one requested default PDU Set importance value as either common to each of the one or more media streams components of the protocol description, or individual for each of the one or more media streams components of the protocol description; and communicate the

determined configuration to one of a Policy Control Function (PCF) and a Network Exposure Function (NEF) to establish the service data flow session with PDU Set processing over a mobile core network.

[0170] The AF may comprise any application function as described herein, for example
5 XRM AF 810. The protocol description may further comprise an indication of at least one of a protocol and a payload type.

[0171] Figure 14 illustrates a method 1400 performed at an Application Function (AF), the method 1400 comprising: determining 1410 a configuration for a service data flow session for an application server (AS) with PDU Set processing based on at least a
10 protocol description including one or more media streams components and at least one request for a default PDU Set importance value; setting 1420 the at least one requested default PDU Set importance value as either common to each of the one or more media streams components of the protocol description, or individual for each of the one or more media streams components of the protocol description; and communicating 1430
15 the determined configuration to one of a Policy Control Function (PCF) and a Network Exposure Function (NEF) to establish the service data flow session with PDU Set processing over a mobile core network.

[0172] In certain embodiments, the method 1400 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a
20 GPU, an auxiliary processing unit, a FPGA, or the like.

[0173] The protocol description may further comprise an indication of at least one of a protocol and a payload type.

[0174] There is presented herein a default PDU Set importance value for PDUs marked by UPF with PDU Set information, whereby such PDUs do not have PDU Set
25 importance indicated by the AS. There is further provided a method for UPF to be configured by the PCF/SMF through PCC/N4 rules with the default PDU Set importance for unmarked PDUs in case a received packet in the downlink does not match the N4 rule protocol description, or alternatively, a received packet in the downlink does match the N4 rule protocol description but is not marked with PDU Set
30 information by the AS. Furthermore, there is provided a method for PCF to determine the default PDU Set importance value for one or more streams of an XR service data flow based at least on one of an AF requested default PDU Set importance and a mobile network operator service level agreement for the service data flow.

[0175] Accordingly, there is provided a method performed by a User Plane Function (UPF), the method comprising of: receiving a protocol data unit (PDU) in a downlink direction wherein the received PDU is subject to PDU Set processing according to a configuration provided by a Session Management Function (SMF), the configuration
5 further comprising a protocol description including one or more media streams components and at least one default PDU Set importance value; determining whether: the received PDU does not match all components of the configuration received from the SMF; or the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set; creating a header for the received PDU,
10 the header including PDU Set information further comprising a PDU Set importance information value determined based on the at least one default PDU Set importance value if either: the received PDU does not match all components of the configuration received from the SMF; or the received PDU does match the protocol description of the configuration from the SMF, but the received PDU is not part of a PDU Set; and routing
15 the received PDU and the header to a radio access network.

[0176] The at least one default PDU Set importance value may be configured by the SMF at least as one of common to all one or more media streams components of the protocol description, and individual for each of the one or more media streams components of the protocol description.

20 [0177] The protocol description may be indicated to a Policy Control Function (PCF) by an Application Function (AF), wherein the at least one default PDU Set importance value is requested by the AF for one or more media streams components of an application service data flow.

[0178] The PCF may verify the AF requested default PDU Set importance value and
25 determines the default PDU Set importance value corresponding to the SMF configuration based at least on one of the AF requested default PDU Set importance value, the protocol description and corresponding one or more media components, and a mobile network operator service level agreement and corresponding policies for charging and control of the application service data flow.

30 [0179] The at least one default PDU Set importance value may be determined by the PCF based on a mobile network operator service level agreement and corresponding policies for charging and control of an application service data flow.

[0180] The UPF may be indicated with a default PDU Set importance value based on Operations, Administration and Management (OAM) procedures.

[0181] The PDU Set information included in the header may comprise at least one of: a PDU Set Sequence Number (PSSN); an indication of an End PDU (E) of the PDU Set; a PDU Sequence Number (PSN) within the PDU Set; a PDU Set Size (PSSize) in bytes; a PDU Set importance (PSI); and an End of Data Burst (EDB) indication.

5 [0182] The protocol description may further comprise indications of at least one a protocol and payload type.

[0183] There is further provided a method performed at an Application Function (AF), the method comprising of: determining a configuration for a service data flow session for an application server (AS) with PDU Set processing based on at least a protocol
10 description including one or more media streams components and at least one request for a default PDU Set importance value; setting the at least one requested default PDU Set importance value as at least one of common to all one or more media streams components of the protocol description, and individual for each of the one or more media streams components of the protocol description; and communicating the
15 determined configuration to one of a Policy Control Function (PCF) and a Network Exposure Function (NEF) to establish the service data flow session with PDU Set processing over a mobile core network.

[0184] It should be noted that the above-mentioned methods and apparatus illustrate rather than limit the invention, and that those skilled in the art will be able to design
20 many alternative arrangements without departing from the scope of the appended claims. The word “comprising” does not exclude the presence of elements or steps other than those listed in a claim, “a” or “an” does not exclude a plurality, and a single processor or other unit may fulfil the functions of several units recited in the claims. Any reference signs in the claims shall not be construed so as to limit their scope.

25 [0185] Further, while examples have been given in the context of particular communication standards, these examples are not intended to be the limit of the communication standards to which the disclosed method and apparatus may be applied. For example, while specific examples have been given in the context of 3GPP, the principles disclosed herein can also be applied to another wireless communication
30 system, and indeed any communication system which uses routing rules.

[0186] The method may also be embodied in a set of instructions, stored on a computer readable medium, which when loaded into a computer processor, Digital Signal Processor (DSP) or similar, causes the processor to carry out the hereinbefore described methods.

[0187] The described methods and apparatus may be practiced in other specific forms.

The described methods and apparatus are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0188] The following abbreviations are relevant in the field addressed by this document:

3GPP, 3rd generation partnership project; 5G, fifth generation; 5GS, 5G System; 5QI, 5G QoS Identifier; AF, application function; AMF, access and mobility function; AR, augmented reality; AS, application server; DL, downlink; NAL, network abstraction layer; PCF, policy control function; PDU, packet data unit; PPS, picture parameter set; PSDB, PDU Set Delay Budget; PSER, PDU Set Error Rate; PSI, PDU Set Importance; PSIH, PDU Set Integrated Handling Indicator; QoE, quality of experience; QoS, quality of service; RAN, radio access network; RTCP, real-time control protocol; RTP, real-time protocol; SDAP, service data adaptation protocol; SMF, session management function; SRTCP, secure real-time control protocol; SRTP, secure real-time protocol; UE, user equipment; UL, uplink; UPF, user plane function; VCL, video coding layer; VMAF, video multi-method assessment function; VPS, video parameter set; VR, virtual reality; XR, extended reality; XR AS, XR application server; and XRM, XR media.

Claims

1. A User Plane Function (UPF), comprising:
 - a processor; and
 - 5 a memory coupled with the processor, the memory comprising instructions executable by the processor to cause the UPF to:
 - receive a configuration, the configuration comprising a protocol description including one or more media stream components and at least one default PDU Set importance value;
 - 10 receive a protocol data unit (PDU) in a downlink direction wherein the received PDU is subject to PDU Set processing according to the configuration;
 - determine whether:
 - the received PDU does not match all components of the received configuration; or
 - 15 the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set;
 - determine a PDU Set importance information value, the determination based on the at least one default PDU Set importance value;
 - create a header for the received PDU, the header including PDU Set information
 - 20 and the determined PDU Set importance information value if either:
 - the received PDU does not match all components of the received configuration; or
 - the received PDU does match the protocol description of the received configuration, but the received PDU is not part of a PDU Set; and
 - 25 route the received PDU and the header to a radio access network.
2. The UPF of claim 1, wherein the at least one default PDU Set importance value is configured as either:
 - common to each of one or more media streams components of the protocol
 - 30 description; or
 - individual for each of the one or more media streams components of the protocol description.

3. The UPF of any claims 1 or 2, wherein the protocol description is indicated to a Policy Control Function (PCF) by an Application Function (AF), and wherein the at least one default PDU Set importance value is requested by the AF for one or more media streams components of an application service data flow.

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4. The UPF of claim 3, wherein the PCF verifies the AF requested default PDU Set importance value and determines the default PDU Set importance value corresponding to the received configuration based at least on one of:

the AF requested default PDU Set importance value;

10 the protocol description and corresponding one or more media components; and
a mobile network operator service level agreement and corresponding policies for charging and control of the application service data flow.

5. The UPF of claim 1 or 2, wherein the at least one default PDU Set importance
15 value is determined by the PCF based on a mobile network operator service level agreement.

6. The UPF of any of claims 1 to 5, further comprising receiving a default PDU Set importance value based on Operations, Administration and Management (OAM)
20 procedures.

7. The UPF of any of claims 1 to 5, wherein the UPF is further caused to receive the configuration comprising the at least one default PDU Set importance value from a Session Management Function (SMF).

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8. The UPF of any claim 1 to 7, wherein the PDU Set information included in the header comprises at least one of:

a PDU Set Sequence Number (PSSN);

an indication of an End PDU (E) of the PDU Set;

30 a PDU Sequence Number (PSN) within the PDU Set;

a PDU Set Size (PSSize) in bytes;

a PDU Set importance (PSI); and

an End of Data Burst (EDB) indication.

9. The UPF of any of claims 1 to 8, wherein the protocol description further comprises an indication of at least one of a protocol and a payload type.
10. A method performed by a User Plane Function (UPF), the method comprising:
- 5 receiving a configuration, the configuration comprising a protocol description including one or more media stream components and at least one default PDU Set importance value;
- receiving a protocol data unit (PDU) in a downlink direction wherein the received PDU is subject to PDU Set processing according to the configuration;
- 10 determining whether:
- the received PDU does not match all components of the received configuration; or
- the received PDU does match the protocol description of the information but that the received PDU is not part of a PDU Set;
- 15 determining a PDU Set importance information value, the determination based on the at least one default PDU Set importance value;
- creating a header for the received PDU, the header including PDU Set information and the determined PDU Set importance information value if either:
- 20 the received PDU does not match all components of the received configuration; or
- the received PDU does match the protocol description of the received configuration, but the received PDU is not part of a PDU Set; and
- routing the received PDU and the header to a radio access network.
- 25 11. The method of claim 10, wherein the at least one default PDU Set importance value is configured as either:
- common to each of one or more media streams components of the protocol description; or
- individual for each of the one or more media streams components of the
- 30 protocol description.
12. The method of any claims 10 or 11, wherein the protocol description is indicated to a Policy Control Function (PCF) by an Application Function (AF), and wherein the at

least one default PDU Set importance value is requested by the AF for one or more media streams components of an application service data flow.

13. The method of claim 12, wherein the PCF verifies the AF requested default PDU Set importance value and determines the default PDU Set importance value corresponding to the received configuration based at least on one of:
the AF requested default PDU Set importance value;
the protocol description and corresponding one or more media components; and
a mobile network operator service level agreement and corresponding policies for charging and control of the application service data flow.

14. The method of claim 10 or 11, wherein the at least one default PDU Set importance value is determined by the PCF based on a mobile network operator service level agreement.

15. The method of any of claims 10 to 14, further comprising receiving a default PDU Set importance value based on Operations, Administration and Management (OAM) procedures.

16. The method of any of claims 10 to 14, further comprising receiving the configuration comprising the at least one default PDU Set importance value from a Session Management Function (SMF).

17. The method of any claim 10 to 16, wherein the PDU Set information included in the header comprises at least one of:

a PDU Set Sequence Number (PSSN);
an indication of an End PDU (E) of the PDU Set;
a PDU Sequence Number (PSN) within the PDU Set;
a PDU Set Size (PSSize) in bytes;
a PDU Set importance (PSI); and
an End of Data Burst (EDB) indication.

18. The method of any of claims 10 to 17, wherein the protocol description further comprises an indication of at least one of a protocol and a payload type.

19. An Application Function (AF) comprising:
a processor; and
a memory coupled with the processor, the memory comprising instructions
5 executable by the processor to cause the AF to:
determine a configuration for a service data flow session for an application server
(AS) with PDU Set processing based on at least a protocol description including one or
more media streams components and at least one request for a default PDU Set
importance value;
10 set the at least one requested default PDU Set importance value as either:
common to each of the one or more media streams components of the
protocol description, and
individual for each of the one or more media streams components of the
protocol description;
15 communicate the determined configuration to one of a Policy Control Function
(PCF) and a Network Exposure Function (NEF) to establish the service data flow
session with PDU Set processing over a mobile core network.
20. The AF of claim 19, wherein the protocol description further comprises an
20 indication of at least one of a protocol and a payload type.