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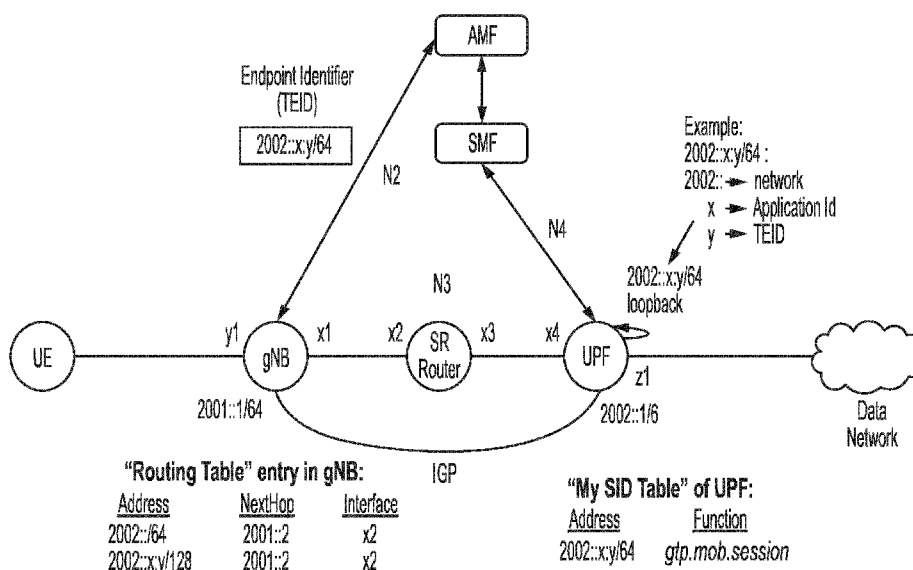


FIG. 6

(57) Abstract: Systems, methods, apparatuses, and computer program products for mapping General Packet Radio Service Tunneling Protocol User Plane (GTP-U) extension headers in Segment Routing version-6 (SRv6). One method may include receiving a data packet from a user equipment. The method may also include encapsulating the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header. The method may further include mapping the GTP-U extension header to a segment routing internet protocol header via a time-length-value field. In addition, the method may include forwarding the GTP-U extension header along with the data packet to a user plane function element.

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TITLE:

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CROSS-REFERENCE TO RELATED APPLICATIONS:

[0001] This application claims priority from U.S. provisional patent application no. 62/843,162 filed on May 3, 2019. The contents of this earlier filed application are hereby incorporated by reference in their entirety.

FIELD:

[0002] Some example embodiments may generally relate to mobile or wireless telecommunication systems, such as Long Term Evolution (LTE) or fifth generation (5G) radio access technology or new radio (NR) access technology, or other communications systems. For example, certain embodiments may relate to systems and/or methods for mapping General Packet Radio Service Tunneling Protocol User Plane (GTP-U) extension headers in Segment Routing version-6 (SRv6).

SUMMARY:

[0003] Some example embodiments are directed to a method. The method may include receiving a data packet from a user equipment. The method may also include encapsulating the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header. The method may further include mapping the GTP-U extension header to a segment routing internet protocol via a time-length-value field. In addition, the method may include forwarding the GTP-U extension header along with the data packet to a user plane function element. Further, the mapping may include mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

[0004] Other example embodiments are directed to an apparatus that may include at least one processor and at least one memory including computer

program code. The at least one memory and the computer program code are configured, with the at least one processor to cause the apparatus at least to receive a data packet from a user equipment. The apparatus may also be caused to encapsulate the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header. The apparatus may further be caused to map the GTP-U extension header to a segment routing internet protocol via a time-length-value field. In addition, the apparatus may be caused to forward the GTP-U extension header along with the data packet to a user plane function element. Further, the mapping may include mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

[0005] Other example embodiments are directed to an apparatus. The apparatus may include means for receiving a data packet from a user equipment. The apparatus may also include means for encapsulating the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header. The apparatus may further include means for mapping the GTP-U extension header to a segment routing internet protocol via a time-length-value field. In addition, the apparatus may include means for forwarding the GTP-U extension header along with the data packet to a user plane function element. Further, the mapping may include mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

[0006] Other example embodiments are directed to a method. The method may include receiving, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and comprising a data packet of a user equipment. The method may also include extracting data from the GTP-U extension header by executing a segment identifier mobility function. The method may further include forwarding the GTP-U extension header to a data network.

[0007] Other example embodiments are directed to an apparatus that may include at least one processor and at least one memory including computer program code. The at least one memory and the computer program code are configured, with the at least one processor to cause the apparatus at least to receive, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and comprising a data packet of a user equipment. The apparatus may also be caused to extract data from the GTP-U extension header by executing a segment identifier mobility function. The apparatus may further be caused to forward the GTP-U extension header to a data network.

[0008] Other example embodiments may be directed to an apparatus. The apparatus may include means for receiving, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and comprising a data packet of a user equipment. The apparatus may also include means for extracting data from the GTP-U extension header by executing a segment identifier mobility function. The apparatus may further include means for forwarding the GTP-U extension header to a data network.

BACKGROUND:

[0009] Examples of mobile or wireless telecommunication systems may include the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN), Long Term Evolution (LTE) Evolved UTRAN (E-UTRAN), LTE-Advanced (LTE-A), MulteFire, LTE-A Pro, and/or fifth generation (5G) radio access technology or new radio (NR) access technology. 5G wireless systems refer to the next generation (NG) of radio systems and network architecture. 5G is mostly built on a new radio (NR), but a 5G (or NG) network can also build on E-UTRA radio. It is estimated that NR provides bitrates on the order of 10-20 Gbit/s or higher, and

can support at least enhanced mobile broadband (eMBB) and ultra-reliable low-latency-communication (URLLC) as well as massive machine type communication (mMTC). NR is expected to deliver extreme broadband and ultra-robust, low latency connectivity and massive networking to support the Internet of Things (IoT). With IoT and machine-to-machine (M2M) communication becoming more widespread, there will be a growing need for networks that meet the needs of lower power, low data rate, and long battery life. It is noted that, in 5G, the nodes that can provide radio access functionality to a user equipment (i.e., similar to Node B in UTRAN or eNB in LTE) may be named gNB when built on NR radio and may be named NG-eNB when built on E-UTRA radio.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0010] For proper understanding of example embodiments, reference should be made to the accompanying drawings, wherein:

[0011] FIG. 1 illustrates an example segment routing header (SRH).

[0012] FIG. 2 illustrates an example Segment Routing version-6 (SRv6) architecture.

[0013] FIG. 3 illustrates an example of a procedure that solves an open issue of how GTP-U tunnel endpoint identifier (TEID) uniquely fills a segment identifier (SID) field along with 3GPP Logical Interface ID (32 bits) or element ID (such as gNB ID).

[0014] FIG. 4 illustrates General Packet Radio Service Tunneling Protocol User Plane (GTP-U) extension headers and their mapping to time-length-value's (TLVs) in a SRv6 header, according to certain example embodiments.

[0015] FIG. 5 illustrates a set of codepoints that are defined in RFC "IPv6 Segment Routing Header."

[0016] FIG. 6 illustrates a procedure for handling GTP-U extension headers in SRv6, according to certain example embodiments.

[0017] FIG. 7 illustrates a SRv6 SID mobility function, according to certain example embodiments.

[0018] FIG. 8 illustrates a case scenario for handling GTP-U extension as part of SRv6 processing, according to certain example embodiments.

[0019] FIG. 9 illustrates a flow diagram of a method, according to an example embodiment.

[0020] FIG. 10 illustrates a flow diagram of another method, according to an example embodiment.

[0021] FIG. 11a illustrates a block diagram of an apparatus, according to an example embodiment.

[0022] FIG. 11b illustrates a block diagram of another apparatus, according to an example embodiment.

[0023] FIG. 12a illustrates a mobility function related to an interworking scenario, according to an example embodiment.

[0024] FIG. 12b illustrates another mobility function related to an interworking scenario, according to an example embodiment.

[0025] FIG. 12c illustrates a further mobility function related to an interworking scenario, according to an example embodiment.

DETAILED DESCRIPTION:

[0026] It will be readily understood that the components of certain example embodiments, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Further, the following is a detailed description of some example embodiments of systems, methods, apparatuses, and computer program products for mapping General Packet Radio Service Tunneling Protocol User Plane (GTP-U) extension headers in Segment Routing version-6 (SRv6).

[0027] The features, structures, or characteristics of example embodiments described throughout this specification may be combined in any suitable manner in one or more example embodiments. For example, the usage of the

phrases “certain embodiments,” “an example embodiment,” “some embodiments,” or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with an embodiment may be included in at least one embodiment. Thus, appearances of the phrases “in certain embodiments,” “an example embodiment,” “in some embodiments,” “in other embodiments,” or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more example embodiments.

[0028] Additionally, if desired, the different functions or steps discussed below may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the described functions or steps may be optional or may be combined. As such, the following description should be considered as merely illustrative of the principles and teachings of certain example embodiments, and not in limitation thereof.

[0029] 3rd Generation Partnership Project Core Network and Terminals responsible for stage 2 aspects within the Core Network (3GPP CT4), has studied 5G user plane alternatives including FS_UPPS (TS 29.281) study item. One alternative solution may include Segment Routing (SR) Internet Protocol Version 6 IPv6 that is under discussions in the Internet Engineering Task Force (IETF). Further, draft draft-ietf-dmm-srv6-mobile-uplane-02 has defined how SRv6 may be used in 3GPP networks.

[0030] According to the draft, each Segment Identifier (SID) may carry a GTP-U tunnel endpoint ID (TEID). An SID may correspond to an SID that represents a specific segment in a segment routing domain. In an example embodiment, the SID type used may be an IPv6 address, which may also be referenced as SRv6 segment or SRv6 SID.

[0031] In a mobile network, a user equipment (UE) session may be mapped 1-for-1 with a specific TEID. The 1-for-1 mapping may be replicated to

replace the GTP endcaps with SRv6 endcaps. According to such an arrangement, it may be possible to minimize the changes required to the entire system, and it may serve as a good starting point for forming the common basis. In this mode, the TEID may be embedded in each SID.

[0032] FIG. 1 illustrates an example segment routing header (SRH). The SR extension header in FIG. 1 may be an IPv6 SR extension header format from 3GPP study item 29.282 v 020. Further, the SRH illustrated in FIG. 1 is related to 3GPP study item (29.282 v 020) Technical Specification Group Core Network and Terminals; Study on user plane protocol in 5GC (Release 16).

[0033] In FIG. 1, a segment list may include a 128 bit IPv6 address representing the nth segment in the segment list. Further, the segment list may be encoded starting from the last segment of the SR policy. This may include, for example, the first element of the segment list (Segment List [0]), which includes the last segment of the SR Policy. In addition, the second element may include the penultimate segment of the SR Policy and so on.

[0034] FIG. 2 illustrates an example Segment routing version-6 (SRv6) architecture. It is noted that 3GPP contribution C4-187269 describes that TEID is somehow included into the SID (shown as of format “U:2:TEID” in FIG. 2). How exactly the fields are used is not explicitly described. Moreover, there is no description with regard to how GTP-U extension headers are handled or addressed in SRv6 architecture. Thus, certain example embodiments address Error Indication and End Marker in SRv6 architecture. Certain example embodiments also address GTP-U extension headers in SRv6.

[0035] In FIG. 2, a packet may be forwarded through the shortest path up to the next segment U:2:TEID, which may be instantiated on the user plane function U (UPF U). In an example embodiment, U may correspond to another gNB in 5G in case of an X2 use case. However, in another example embodiment, for LTE, UPF U may be another eNB, SG-W, or P-GW. Once the packet arrives at UPF U, the function may be executed. The function may

also indicate to the UPF U the specific Rule Set and the Apply Action that should be applied to that packet data unit (PDU). Once the particular UPF functionality is triggered, the UPF may recover the TEID and quality of service (QoS) marking from the SRv6 segment arguments.

[0036] FIG. 3 illustrates a procedure that solves the open issue of how TEID uniquely fills the SID field along with 3GPP Logical Interface ID (32 bits) or element ID (such as gNB ID). Currently, a problem exists that there is no guidance on how GTP-U extension headers are addressed in SRv6, or any other alternative architectures. Thus, according to certain example embodiments, Error Indication and End Marker may be addressed in SRv6 architecture. Certain example embodiments may also address GTP-U extension header mapping in SRv6 header.

[0037] GTP-U tunneling has been used, and certain example embodiments provide a way of replacing GTP-U by SR. Further, some of the PDU session user plane protocol may be embedded as arguments in SID. However, certain example embodiments may provide a way of mapping PDU (T-PDU), extension headers, Error Indication, and End Marker to SRv6 header with a TVL field as defined here. The SRv6 header with the TLV field containing GTP-U extensions may also be included into IPv6 packets with zero segment list (FIG. 4).

[0038] FIG. 4 illustrates General Packet Radio Service Tunneling Protocol User Plane (GTP-U) extension headers and their mapping to time-length-value's (TLVs) in a SRv6 header, according to certain example embodiments. In an example embodiment, the TLV in SRv6 may be an encoding scheme that is used for optional information elements in SRv6. As illustrated in FIG. 4, PDU (T-PDU), extension headers, Error Indication, and End Marker may be mapped to TLVs of SRv6. TLVs may already be defined in draft "draft-ietf-6man-segment-routing-header-18." However, the draft defines only TLVs for the hash message authentication code (HMAC) and PAding. The presence of TLVs can be recognized by observing that the Hdr Ext Len

exceeds the Last Entry element in the Segment List. For more efficient packet processing also a flag bit as per FIG. 4 should be used.

[0039] In FIG. 4, various fields may be present. In one example embodiment, the fields may include a type field, length field, sub-type field, and variable field. According to an example embodiment, the type field may include binary code, and may be a codepoint value that represents GTP-U extension headers, and require SRH TLV registration. The type field may also provide an indication of the kind of field that the part of the message represents. In one example embodiment, the type field may be of a value 7. According to another example embodiment, the type field may be assigned by Internet Assigned Numbers Authority (IANA). This may be a GTP-U specific case, and may require SRH TLV registration.

[0040] In example embodiment, the SRH TLV registration may include a request for the creation of a new IANA managed registry to identify SRH TLVs. The registration procedure may be identified as “Expert Review” as defined in RFC8126. In an example embodiment, a registry name may include “Segment Routing Header TLVs.” Further, a TLV may be identified through an unsigned 8 bit codepoint value. With regard to codepoint values, FIG. 5 illustrates a set of codepoints that are defined in RFC “IPv6 Segment Routing Header.”

[0041] As to length, the length field may define a variable length. In an example embodiment, the variable length may be measured in bytes. Further, the sub-type field may represent a type of GTP extension and “Next Extension Header Type” may represent the next GTP extension header type. The message type of GTP-U is described in 3GPP TS 29.281 and/or it may be just be a GTP-U extension header. If a message type is PDU (T-PDU), then TEID may be part of the PDU message and the tunnel destination address may or may not have TEID. However, in the case of GTP-U extension header (without T-PDU), a “Message type” value may be set to 0, with a sub-type

specifying the GTP-U extension header type value as described in 3GPP TS 29.281.

[0042] According to an example embodiment, a sub-type field in the case of GTP-U extension header, may represent a type of GTP extension header. In certain example embodiments, the type of GTP extension header may include a packet data convergence protocol (PDCP) PDU number, new radio (NR) radio access network (RAN) container, PDU session container, and others. In cases other than GTP-U extension header, the sub-type value may be set to a default of 0. According to another example embodiment, the content field of the TLV in FIG. 4 may be a 3GPP specific GTP-U extension header content, GTP-U error indication, GTP-U EndMarker content, or any other GTP-U specific content as described in 3GPP TS 29 281.

[0043] According to an example embodiment, GTP-U extension headers may carry control information and the content may be specified in 3GPP TS 129.281. In an example embodiment, the GTP-U extension headers may be part of the GTP-U header, and there may be multiple extension types defined by 3GPP. For example, some extension types may include a radio access network (RAN) container, Xw RAN container, new radio (NR) RAN container, and a PDE session container.

[0044] In an example embodiment, the RAN container extension header may be transmitted in a G-PDU over the X2 user plane interface between eNodeBs (eNBs). That is, the G-PDU may be a user data packet (T-PDU) plus a GTP-U header that is sent between GTP network nodes. Further, the RAN container may have a variable length, and the content of the RAN container is specified in 3GPP TS 36.425.

[0045] According to an example embodiment, the Xw RAN container may be an extension header that is transmitted in a G-PDU over the Xw user plane interface between the eNB and the wireless local area network (WLAN) transmission (WT). The Xw RAN container may also have a variable length and is specified in 3GPP TS 36.465.

[0046] In another example embodiment, the NR RAN container may be an extension header that is transmitted in a G-PDU over the X2-U, Xn-U and F1-U user plane interfaces, within Next Generation Radio Access Network (NGRAN) and for dual connectivity (EN-DC) within the Evolved Universal Terrestrial Access Network (E-UTRAN). The NR RAN container may also have a variable length, and the NR RAN container contents are specified in 3GPP TS 38.425.

[0047] According to an example embodiment, the PDU session container may be an extension header transmitted in a G-PDU over the N3 and N9 user plane interfaces between NG RAN and UPF, or between two UPFs. Further, the PDU session container may have a variable length, and the content of the PDU session container is specified in 3GPP TS 38.415. Even though the PDU session container is addressed as arguments in SID, the rest of the GTP-U extension headers are not addressed. Thus, certain example embodiments may provide a way of handling the GTP-U extension headers in SRv6 enhanced mode, as defined in C4-187269.

[0048] FIG. 6 illustrates a procedure for handling GTP-U extension headers in SRv6, according to certain example embodiments. For example, a packet from a UE may be encapsulated into IPv6 headers at the gNB and then forwarded to the UPF. The encapsulated header may have a source address gNB address, and as a destination address, the UPF's address. The application ID+ TEID may be encoded in the UPF1's address as <UPF1::Interface/Element ID:TEID> so that the 64 least significant bits of the interface ID represent the tunnel endpoint value upwards. Similarly, for packets in the downlink (DL) direction, the address of the gNB may have the downwards tunnel endpoint value encoded in the interface ID part of the address. In an example embodiment, the interface IDs may be set based on control plane signaling as in the case of GTP tunneling.

[0049] FIG. 7 illustrates a SRv6 SID mobility function, according to certain example embodiments. As illustrated in FIG. 7, a method provides a SRv6

SID mobility function “gtp.mob.session” that helps in extracting data from TLVs of SRH for processing the packet locally. In an example embodiment, the “gtp.mob.session” SID must always be the last SID in the case of SRH.

[0050] FIG. 8 illustrates a case scenario for handling GTP-U extension as part of SRv6 processing, according to certain example embodiments. For example, FIG. 8 illustrates a case of a PDU session user plane protocol (one of the GTP-U extension headers), which is used to convey control information. In certain example embodiments, the control information may include a QoS flow ID (QFI) and a reflective QoS indicator (RQI) associated with a PDU session. In an example embodiment, the PDU session user plane protocol data may be conveyed by the GTP-U protocol, and more specifically, by means of the PDU session container in GTP-U extension header as defined in TS 29.281.

[0051] As illustrated in FIG. 8, a set up is provided where only GTP-U extension header “PDU session container” without “Message type” is addressed in SRv6 SRH. In addition, from FIG. 8, based on control plane signaling, a tunnel is created between gNB and UPF. When the user plane traffic arrives at the gNB from the UE (uplink), the user plane packets may be sent using SRv6 instead of GTP-U. According this example embodiment, the user plane packet may be encapsulated in SRv6 and control information of the GTP-U headers (including GTP-U extension headers if any) may be mapped to SRv6. Thus, according to certain example embodiments, it is possible to handle, carry, or map T-PDU extension headers, Error indication, and End Marker to SRv6. Further, when the user plane packet WRT bearer is sent from gNB, GTP-U specific information (as illustrated in the example of FIG. 8 with GTP-U extension header “PDU session container”) may be mapped to SRv6’s TLV and sent to the UL direction.

[0052] FIG. 9 illustrates a flow diagram of a method according to an example embodiment. In certain example embodiments, the flow diagram of FIG. 9 may be performed by a network entity or network node in a 3GPP system, such as LTE or 5G NR. For instance, in some example embodiments, the

method of FIG. 9 may be performed by the apparatus of FIG. 11a, which may include a base station, eNB or gNB.

[0053] According to one example embodiment, the method of FIG. 9 may include initially, at 100, receiving a data packet from a UE. The method may also include, at 105, encapsulating the data packet into an IPv6 with SRH header. Further, the method may include, at 110, mapping the GTP-U extension header to a segment routing internet protocol header such as SRv6 SRH, via a time-length-value field. In addition, at 115, the method may include forwarding the GTP-U extension header along with the data packet to a user plane function element.

[0054] In an example embodiment, the mapping may include mapping other fields including, for example, Error code and End Marker, to the segment routing internet protocol. According to an example embodiment, the mapping may include mapping the GTP-U extension header to a TLV of the segment routing internet protocol using the time-length-value field. In another example embodiment, the segment routing internet protocol header may carry control information. In a further example embodiment, the time-length-value may include one or a combination of a general packet radio service tunneling protocol user plane tunnel endpoint identifier, an element identifier, and an interface identifier. According to an example embodiment, the time-length-value field may be applied in a segment routing header. According to another example embodiment, the GTP-U extension header may be one of a RAN container type, Xw RAN container type, NR RAN container type, or PDU session container type.

[0055] In a further example embodiment, the segment routing internet protocol header may include an application identifier and a TEID. In another example embodiment, the encapsulating may be performed with the segment routing internet protocol header and the segment routing header. In a further example embodiment, the mapping may include mapping an error code and

an end marker to the segment routing internet protocol header via the time-length-value field.

[0056] FIG. 10 illustrates a flow diagram of a method, according to an example embodiment. In certain example embodiments, the flow diagram of FIG. 10 may be performed by a network entity or network node in a 3GPP system, such as LTE or 5G NR. For instance, in some example embodiments, the method of FIG. 10 may be performed by the apparatus of FIG. 11a, which may include network elements such as a UPF element.

[0057] According to one example embodiment, the method of FIG. 10 may include initially, at 200, receiving, from a network element, a GTP-U extension header that is mapped to a segment routing internet protocol header, and including a data packet of a user equipment. The method may also include, at 205, extracting data from the GTP-U extension header by executing a segment identifier mobility function. According to an example embodiment, extracting the data may include extracting GTP-U related content from the GTP-U extension header in the segment routing internet protocol header. In addition, the method may include, at 210, processing the extracted GTP-U related content as per the GTP-U extension header.

[0058] In an example embodiment, the method may include, at 215, forwarding the GTP-U extension header including the data packet of the user UE to a data network. According to an example embodiment, the forwarding may include forwarding the data packet according to local policies. According to a further example embodiment, the data packet may be forwarded to the data network according to an application identifier and a TEID located in a time-length-value field of the segment routing internet protocol header. In another example embodiment, the segment routing internet protocol header may carry control information. According to a further example embodiment, the GTP-U extension header may be part of a GTP header. In another example embodiment, the GTP-U extension header may be one of a RAN container type, Xw RAN container type, NR RAN container type, or PDU session

container type. According to another example embodiment, the GTP-U extension header is forwarded to the data network according to an application identifier and a TEID located in the G-PDU (T-PDU) in SRv6 SRH. In a further example embodiment, the GTP-U extension header may be received in a segment routing internet protocol environment such as a SRv6 environment. In another example embodiment, the mapping may be configured via third generation partnership project signaling, or via software defined networking functions.

[0059] FIG. 11a illustrates an example of an apparatus 10 according to an example embodiment. In an example embodiment, apparatus 10 may be a node, host, or server in a communication network or serving such a network. For example, apparatus 10 may be a satellite, base station, a Node B, an evolved Node B (eNB), 5G Node B or access point, next generation Node B (NG-NB or gNB), and/or WLAN access point, SR router, or UPF element associated with a radio access network (RAN), such as an LTE network, 5G or NR. In certain example embodiments, apparatus 10 may be an eNB in LTE or gNB, or UPF element in 5G.

[0060] It should be understood that, in some example embodiments, apparatus 10 may be comprised of an edge cloud server as a distributed computing system where the server and the radio node may be stand-alone apparatuses communicating with each other via a radio path or via a wired connection, or they may be located in a same entity communicating via a wired connection. For instance, in certain example embodiments where apparatus 10 represents a gNB, it may be configured in a central unit (CU) and distributed unit (DU) architecture that divides the gNB functionality. In such an architecture, the CU may be a logical node that includes gNB functions such as transfer of user data, mobility control, radio access network sharing, positioning, and/or session management, etc. The CU may control the operation of DU(s) over a front-haul interface. The DU may be a logical node that includes a subset of the gNB functions, depending on the functional split option. It should be noted

that one of ordinary skill in the art would understand that apparatus 10 may include components or features not shown in FIG. 11a.

[0061] As illustrated in the example of FIG. 11a, apparatus 10 may include a processor 12 for processing information and executing instructions or operations. Processor 12 may be any type of general or specific purpose processor. For example, processor 12 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples. While a single processor 12 is shown in FIG. 11a, multiple processors may be utilized according to other embodiments. For example, it should be understood that, in certain embodiments, apparatus 10 may include two or more processors that may form a multiprocessor system (e.g., in this case processor 12 may represent a multiprocessor) that may support multiprocessing. In certain embodiments, the multiprocessor system may be tightly coupled or loosely coupled (e.g., to form a computer cluster).

[0062] According to certain example embodiments, processor 12 may perform functions associated with the operation of apparatus 10, which may include, for example, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 10, including processes illustrated in FIGs. 1-10 and 12a-12c.

[0063] Apparatus 10 may further include or be coupled to a memory 14 (internal or external), which may be coupled to processor 12, for storing information and instructions that may be executed by processor 12. Memory 14 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory

device and system, fixed memory, and/or removable memory. For example, memory 14 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, hard disk drive (HDD), or any other type of non-transitory machine or computer readable media. The instructions stored in memory 14 may include program instructions or computer program code that, when executed by processor 12, enable the apparatus 10 to perform tasks as described herein.

[0064] In an embodiment, apparatus 10 may further include or be coupled to (internal or external) a drive or port that is configured to accept and read an external computer readable storage medium, such as an optical disc, USB drive, flash drive, or any other storage medium. For example, the external computer readable storage medium may store a computer program or software for execution by processor 12 and/or apparatus 10 to perform the methods illustrated in FIGs. 1-10 and 12a-12c.

[0065] In certain example embodiments, apparatus 10 may also include or be coupled to one or more antennas 15 for transmitting and receiving signals and/or data to and from apparatus 10. Apparatus 10 may further include or be coupled to a transceiver 18 configured to transmit and receive information. The transceiver 18 may include, for example, a plurality of radio interfaces that may be coupled to the antenna(s) 15. The radio interfaces may correspond to a plurality of radio access technologies including one or more of GSM, NB-IoT, LTE, 5G, WLAN, Bluetooth, BT-LE, NFC, radio frequency identifier (RFID), ultrawideband (UWB), MulteFire, and the like. The radio interface may include components, such as filters, converters (for example, digital-to-analog converters and the like), mappers, a Fast Fourier Transform (FFT) module, and the like, to generate symbols for a transmission via one or more downlinks and to receive symbols (for example, via an uplink).

[0066] As such, transceiver 18 may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) 15 and demodulate information received via the antenna(s) 15 for further processing by other

elements of apparatus 10. In other embodiments, transceiver 18 may be capable of transmitting and receiving signals or data directly. Additionally or alternatively, in some embodiments, apparatus 10 may include an input and/or output device (I/O device).

[0067] In an embodiment, memory 14 may store software modules that provide functionality when executed by processor 12. The modules may include, for example, an operating system that provides operating system functionality for apparatus 10. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 10. The components of apparatus 10 may be implemented in hardware, or as any suitable combination of hardware and software.

[0068] According to some embodiments, processor 12 and memory 14 may be included in or may form a part of processing circuitry or control circuitry. In addition, in some embodiments, transceiver 18 may be included in or may form a part of transceiving circuitry.

[0069] As used herein, the term “circuitry” may refer to hardware-only circuitry implementations (e.g., analog and/or digital circuitry), combinations of hardware circuits and software, combinations of analog and/or digital hardware circuits with software/firmware, any portions of hardware processor(s) with software (including digital signal processors) that work together to cause an apparatus (e.g., apparatus 10) to perform various functions, and/or hardware circuit(s) and/or processor(s), or portions thereof, that use software for operation but where the software may not be present when it is not needed for operation. As a further example, as used herein, the term “circuitry” may also cover an implementation of merely a hardware circuit or processor (or multiple processors), or portion of a hardware circuit or processor, and its accompanying software and/or firmware. The term circuitry may also cover, for example, a baseband integrated circuit in a server, cellular network node or device, or other computing or network device.

[0070] As introduced above, in certain embodiments, apparatus 10 may be a network node or RAN node, such as a base station, access point, Node B, eNB, gNB, WLAN access point, or the like. According to certain embodiments, apparatus 10 may be controlled by memory 14 and processor 12 to perform the functions associated with any of the embodiments described herein, such as the flow or signaling diagrams illustrated in FIGs. 1-10 and 12a-12c.

[0071] For instance, in one embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to receive a data packet from a UE. Apparatus 10 may also be controlled by memory 14 and processor 12 to encapsulate the data packet into a GTP-U extension header. Apparatus 10 may further be controlled by memory 14 and processor 12 to map the GTP-U extension header to a segment routing internet protocol header via a time-length-value field. In addition, the apparatus 10 may be controlled by memory 14 and processor 12 to forward the GTP-U extension header along with the data packet to a user plane function element. In an example embodiment, the mapping may include mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

[0072] According to another embodiment, apparatus 10 may be controlled by memory 14 and processor 12 to receive, from a network element, a GTP-U extension header that is mapped to a segment routing internet protocol header, and includes a data packet of a user equipment. Apparatus 10 may further be controlled by memory 14 and processor 12 to extract data from the GTP-U extension header by executing a segment identifier mobility function. In addition, apparatus 10 may be controlled by memory 14 and processor 12 to forward the GTP-U extension header to a data network.

[0073] FIG. 11b illustrates an example of an apparatus 20 according to another example embodiment. In an embodiment, apparatus 20 may be a node or element in a communications network or associated with such a network, such

as a UE, mobile equipment (ME), mobile station, mobile device, stationary device, IoT device, or other device. As described herein, UE may alternatively be referred to as, for example, a mobile station, mobile equipment, mobile unit, mobile device, user device, subscriber station, wireless terminal, tablet, smart phone, IoT device, sensor or NB-IoT device, or the like.

[0074] In some example embodiments, apparatus 20 may include one or more processors, one or more computer-readable storage medium (for example, memory, storage, or the like), one or more radio access components (for example, a modem, a transceiver, or the like), and/or a user interface. In some embodiments, apparatus 20 may be configured to operate using one or more radio access technologies, such as GSM, LTE, LTE-A, NR, 5G, WLAN, WiFi, NB-IoT, Bluetooth, NFC, MulteFire, and/or any other radio access technologies. It should be noted that one of ordinary skill in the art would understand that apparatus 20 may include components or features not shown in FIG. 11b.

[0075] As illustrated in FIG. 11b, apparatus 20 may include or be coupled to a processor 22 for processing information and executing instructions or operations. Processor 22 may be any type of general or specific purpose processor. In fact, processor 22 may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples. While a single processor 22 is shown in FIG. 11b, multiple processors may be utilized according to other embodiments. For example, it should be understood that, in certain example embodiments, apparatus 20 may include two or more processors that may form a multiprocessor system (e.g., in this case processor 22 may represent a multiprocessor) that may support multiprocessing. According to certain example embodiments, the multiprocessor system may be tightly coupled or loosely coupled (e.g., to form a computer cluster).

[0076] Processor 22 may perform functions associated with the operation of apparatus 20 including, as some examples, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus 20, including processes illustrated in FIGs. 1-8.

[0077] Apparatus 20 may further include or be coupled to a memory 24 (internal or external), which may be coupled to processor 22, for storing information and instructions that may be executed by processor 22. Memory 24 may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and/or removable memory. For example, memory 24 can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, hard disk drive (HDD), or any other type of non-transitory machine or computer readable media. The instructions stored in memory 24 may include program instructions or computer program code that, when executed by processor 22, enable the apparatus 20 to perform tasks as described herein.

[0078] In an embodiment, apparatus 20 may further include or be coupled to (internal or external) a drive or port that is configured to accept and read an external computer readable storage medium, such as an optical disc, USB drive, flash drive, or any other storage medium. For example, the external computer readable storage medium may store a computer program or software for execution by processor 22 and/or apparatus 20 to perform any of the methods illustrated in FIGs. 1-8.

[0079] In some embodiments, apparatus 20 may also include or be coupled to one or more antennas 25 for receiving a downlink signal and for transmitting via an uplink from apparatus 20. Apparatus 20 may further include a transceiver 28 configured to transmit and receive information. The transceiver

28 may also include a radio interface (e.g., a modem) coupled to the antenna 15. The radio interface may correspond to a plurality of radio access technologies including one or more of GSM, LTE, LTE-A, 5G, NR, WLAN, NB-IoT, Bluetooth, BT-LE, NFC, RFID, UWB, and the like. The radio interface may include other components, such as filters, converters (for example, digital-to-analog converters and the like), symbol demappers, signal shaping components, an Inverse Fast Fourier Transform (IFFT) module, and the like, to process symbols, such as OFDMA symbols, carried by a downlink or an uplink.

[0080] For instance, transceiver 28 may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) 25 and demodulate information received via the antenna(s) 25 for further processing by other elements of apparatus 20. In other embodiments, transceiver 28 may be capable of transmitting and receiving signals or data directly. Additionally or alternatively, in some embodiments, apparatus 20 may include an input and/or output device (I/O device). In certain embodiments, apparatus 20 may further include a user interface, such as a graphical user interface or touchscreen.

[0081] In an embodiment, memory 24 stores software modules that provide functionality when executed by processor 22. The modules may include, for example, an operating system that provides operating system functionality for apparatus 20. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus 20. The components of apparatus 20 may be implemented in hardware, or as any suitable combination of hardware and software. According to an example embodiment, apparatus 20 may optionally be configured to communicate with apparatus 10 via a wireless or wired communications link 70 according to any radio access technology, such as NR.

[0082] According to certain example embodiments, processor 22 and memory 24 may be included in or may form a part of processing circuitry or control circuitry. In addition, in some embodiments, transceiver 28 may be included in or may form a part of transceiving circuitry.

[0083] As discussed above, according to certain example embodiments, apparatus 20 may be a UE, mobile device, mobile station, ME, IoT device and/or NB-IoT device, for example. According to certain embodiments, apparatus 20 may be controlled by memory 24 and processor 22 to perform the functions associated with example embodiments described herein. For example, in some embodiments, apparatus 20 may be configured to perform one or more of the processes depicted in any of the flow charts or signaling diagrams described herein, such as the flow diagrams illustrated in FIGs. 1-8.

[0084] FIG. 12a, illustrates a mobility function related to an interworking scenario, according to an example embodiment. Further, FIG. 12b illustrates another mobility function related to an interworking scenario, and FIG. 12c illustrates a further mobility function related to an interworking scenario. Certain mobility functions have been described in draft-ietf-dmm-srv6-mobile-uplane-04 that are related to interworking scenarios. However, the described interworking scenarios do not consider how GTP-U extension headers are addressed in SRv6, and how Error Indication and End Marker are addressed in SRv6 architecture. Therefore, FIGs. 12a-12c provide certain mobility functions related to interworking scenarios that consider GTP-U extension headers in SRv6, and Error Indication and End Marker in SRv6 according to the various example embodiments described herein.

[0085] In FIG. 12a, there is provided an endpoint function with encapsulation for IPv6/GTP tunnel (End.M.GTP6.E) in an interworking scenario for downlink toward gNB using IPv6/GTP. Specifically, according to an example embodiment, step 5 may be included for storing extension headers, Error Indication, and End Marker if any in SRv6 SRH TLV's. In addition, step 10 may be included to set extension headers, Error Indication, and End Marker

if any to a GTP-U header. Certain example embodiments may also be incorporated into Note 2 of FIG. 12a, wherein if a valid TEID is not available in the argument space of SID, SRv6 TLV's may need to be checked.

[0086] In FIG. 12b, there is provided an endpoint function with decapsulation into SR policy function (End.M.GTP6.D), which may be used in an interworking scenario for uplink toward gNB using IPv6/GTP. According to an example embodiment, Ref1 may be included, which may specify that mapping of GTP-U T-PDU, extension headers, Error Indication, and End Marker to SRv6 TLV may be handled as part of this step.

[0087] In FIG. 12c, there is provided an endpoint function with encapsulation for IPv4/GTP tunnel function (End.M.GTP4.E), which may be used in the downlink when interworking with the gNB using IPv4/GTP. Specifically, according to an example embodiment, step 5 may be added. As illustrated in FIG. 12c, step 5 specifies that if GTP-U extension headers, Error Indication, and/or End Marker is part of SRv6 SRH TLV, then GTP headers are pushed with respective fields from S.

[0088] Certain example embodiments described herein provide several technical improvements, enhancements, and/or advantages. In some example embodiments, it may be possible to address GTP-U extension headers in a SRv6 architecture in enhanced mode. For example, it may be possible to address how GTP-U extension headers are handled in SRv6 in enhanced mode, and how Error Indication and End Marker are addressed in SRv6 architecture.

[0089] According to other example embodiments, it may be possible to harmonize the use of SRv6 across RAN and the core network. For example, it may be possible to have the same mapping applied for N3, N9, X2, NGAP, S1u, and S5. Further, by maintaining GTP-U semantics without requiring full GTP-U stack, there are no changes to control plane signaling. In addition, interworking with legacy network equipment that do not support SRv6 may become more straightforward. Additionally, in certain example embodiments,

it may be possible to decrease overhead as GTP/UDP encapsulation is skipped, and all the other SRv6 benefits may be exploited.

[0090] A computer program product may comprise one or more computer-executable components which, when the program is run, are configured to carry out some example embodiments. The one or more computer-executable components may be at least one software code or portions of it. Modifications and configurations required for implementing functionality of an example embodiment may be performed as routine(s), which may be implemented as added or updated software routine(s). Software routine(s) may be downloaded into the apparatus.

[0091] As an example, software or a computer program code or portions of it may be in a source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers may include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers. The computer readable medium or computer readable storage medium may be a non-transitory medium.

[0092] In other example embodiments, the functionality may be performed by hardware or circuitry included in an apparatus (e.g., apparatus 10 or apparatus 20), for example through the use of an application specific integrated circuit (ASIC), a programmable gate array (PGA), a field programmable gate array (FPGA), or any other combination of hardware and software. In yet another example embodiment, the functionality may be implemented as a signal, a non-tangible means that can be carried by an electromagnetic signal downloaded from the Internet or other network.

[0093] According to an example embodiment, an apparatus, such as a node, device, or a corresponding component, may be configured as circuitry, a computer or a microprocessor, such as single-chip computer element, or as a chipset, including at least a memory for providing storage capacity used for arithmetic operation and an operation processor for executing the arithmetic operation.

[0094] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. Although the above embodiments refer to 5G NR and LTE technology, the above embodiments may also apply to any other present or future 3GPP technology, such as LTE-advanced, and/or fourth generation (4G) technology.

[0095] A first embodiment is directed to a method that may include receiving a data packet from a user equipment. The method may also include encapsulating the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header. The method may further include mapping the GTP-U extension header to a segment routing internet protocol via a time-length-value field. In addition, the method may include forwarding the GTP-U extension header along with the data packet to a user plane function element.

[0096] In a variant, the mapping may include mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

[0097] In a variant, the segment routing internet protocol header may carry control information.

[0098] In a variant, the time-length-value may include one or a combination of a general packet radio service tunneling protocol user plane tunnel endpoint identifier, an element identifier, and an interface identifier.

[0099] In a variant, the time-length-value field may be applied in a segment routing header.

[0100] In a variant, the GTP-U extension header may be one of a radio access network container type, an Xw radio access network container type, a new radio access network container type, or a packet data unit session container type.

[0101] In a variant, the segment routing internet protocol header may include an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier.

[0102] In a variant, the encapsulating may be performed with the segment routing internet protocol header and the segment routing header.

[0103] In a variant, the mapping may also include mapping an error code and an end marker to the segment routing internet protocol header via the time-length-value field.

[0104] In a variant, the mapping may also include mapping T-PDU of GTP-U to the segment routing internet protocol header via the time-length-value field.

[0105] A second embodiment may be directed to a method that may include receiving, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and including a data packet of a user equipment. The method may also include extracting data from the GTP-U extension header by executing a segment identifier mobility function. The method may further include forwarding the GTP-U extension header to a data network.

[0106] In a variant, extracting the data may include extracting GTP-U related content from the GTP-U extension header in the segment routing internet protocol header.

[0107] In a variant, extracting the data may include extracting T-PDU of GTP-U related content from the GTP-U extension header in the segment routing internet protocol header.

[0108] In a variant, the method may also include processing the extracted GTP-U related content as per the GTP-U extension header.

[0109] In a variant, forwarding may include forwarding the data packet according to local policies.

[0110] In a variant, the user packet may be forwarded to the data network according to an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier located in a time-length-value field of the segment routing internet protocol header. In a variant, a transfer protocol data unit may or may not include the GTP-U extension header in a segment routing internet protocol header.

[0111] In a variant, the segment routing internet protocol header may carry control information.

[0112] In a variant, the GTP-U extension header may be one of a radio access network container type, an Xw radio access network container type, a new radio access network container type, or a packet data unit session container type.

[0113] In a variant, the GTP-U extension header may be forwarded to the data network according to an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier located in the GTP-U extension header.

[0114] In a variant, the GTP-U extension header may be received in a segment routing internet protocol environment.

[0115] Another embodiment is directed to an apparatus including at least one processor and at least one memory including computer program code. The at least one memory and the computer program code may be configured, with the at least one processor, to cause the apparatus at least to perform the method

according to the first embodiment or the second embodiment or any of their variants discussed above.

[0116] Another embodiment is directed to an apparatus that may include circuitry configured to perform the method according to the first embodiment or the second embodiment or any of their variants.

[0117] Another embodiment is directed to an apparatus that may include means for performing the method according to the first embodiment or the second embodiment or any of their variants.

[0118] Another embodiment is directed to a computer readable medium including program instructions stored thereon for performing at least the method according to the first embodiment or the second embodiment or any of their variants

[0119] Partial Glossary

[0120] 3GPP CT4	3GPP TSG CT WG4 (CT4)
[0121] eNB	eNodeB
[0122] gNB	New Radio (5G) node B (BTS)
[0123] GTP-U	GPRS Tunneling Protocol User Plane
[0124] ID	Identifier
[0125] IETF	Internet Engineering Task Force
[0126] NR	New Radio
[0127] NR-U	New Radio-Unlicensed
[0128] SID	Segment ID
[0129] SR	Segment Routing
[0130] SRH	Segment Routing Header
[0131] SRv6	Segment Routing IPv6
[0132] TEID	GTPU tunnel Endpoint ID
[0133] UE	User Equipment
[0134] UPF	User Plane Function
[0135] UL	Uplink

WE CLAIM:

1. A method, comprising:
 - receiving a data packet from a user equipment;
 - encapsulating the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header;
 - mapping the GTP-U extension header to a segment routing internet protocol via a time-length-value field; and
 - forwarding the GTP-U extension header along with the data packet to a user plane function element,wherein the mapping comprises mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.
2. The method according to claim 1, wherein the segment routing internet protocol header carries control information.
3. The method according to claims 1 or 2, wherein the time-length-value comprises one or a combination of general packet radio service tunneling protocol user plane tunnel endpoint identifier, an element identifier, and an interface identifier.
4. The method according to any of claims 1-3, wherein the time-length-value field is applied in a segment routing header.
5. The method according to any of claims 1-4, wherein the GTP-U extension header is one of a radio access network type, an Xw radio access network container type, a new radio access network container type, or a packet

data unit session container type.

6. The method according to any of claims 1-5, wherein the segment routing internet protocol header comprises an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier.

7. The method according to any of claims 1-6, wherein the encapsulating is performed with the segment routing internet protocol header and the segment routing header.

8. The method according to any of claims 1-7, wherein the mapping further comprises mapping an error code and an end marker to the segment routing internet protocol header via the time-length-value field.

9. The method according to any of claims 1-8, wherein the mapping further comprises mapping a transfer protocol data unit (T-PDU) of the GTP-U to the segment routing internet protocol header via the time-length-value field.

10. A method, comprising:

receiving, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and comprising a data packet of a user equipment,

extracting data from the GTP-U extension header by executing a segment identifier mobility function; and

forwarding the GTP-U extension header to a data network.

11. The method according to claim 10, wherein extracting the data

comprises extracting GTP-U related content from the GTP-U extension header in the segment routing internet protocol header.

12. The method according to claims 10 or 11, wherein extracting the data comprises extracting a transfer protocol data unit (T-PDU) of GTP-U related content from the GTP-U extension header in the segment routing internet protocol header.

13. The method according to any of claims 10-12, further comprising processing the extracted GTP-U related content as per the GTP-U extension header.

14. The method according to any of claims 10-13, wherein the forwarding comprises forwarding the data packet according to local policies.

15. The method according to any of claims 10-14, wherein the data packet is forwarded to the data network according to an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier located in a time-length-value field of the segment routing internet protocol header.

16. The method according to any of claims 10-15, wherein a transfer protocol data unit comprises the GTP-U extension header in a segment routing internet protocol header.

17. The method according to any of claims 10-16, wherein the segment routing internet protocol header carries control information.

18. The method according to any of claims 10-17, wherein the GTP-U extension header is one of a radio access network container type, an Xw radio

access network container type, a new radio access network container type, or a packet data unit session container type.

19. The method according to any of claims 10-18, wherein the GTP-U extension header is forwarded to the data network according to an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier located in the GTP-U extension header.

20. The method according to any of claims 10-19, wherein the GTP-U extension header is received in a segment routing internet protocol environment.

21. An apparatus, comprising:
at least one processor; and
at least one memory comprising computer program code,
the at least one memory and the computer program code are configured, with the at least one processor to cause the apparatus at least to
receive a data packet from a user equipment;
encapsulate the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header;
map the GTP-U extension header to a segment routing internet protocol via a time-length-value field; and
forward the GTP-U extension header along with the data packet to a user plane function element,
wherein the mapping comprises mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

22. The apparatus according to claim 21, wherein the segment routing internet protocol header carries control information.

23. The apparatus according to claims 21 or 22, wherein the time-length-value comprises one or a combination of general packet radio service tunneling protocol user plane tunnel endpoint identifier, an element identifier, and an interface identifier.

24. The apparatus according to any of claims 21-23, wherein the time-length-value field is applied in a segment routing header.

25. The apparatus according to any of claim 21-24, wherein the GPT-U extension header is one of a radio access network type, an Xw radio access network container type, a new radio access network container type, or a packet data unit session container type.

26. The apparatus according to any of claims 21-25, wherein the segment routing internet protocol header comprises an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier.

27. The apparatus according to any of claims 21-26, wherein the encapsulating is performed with the segment routing internet protocol header and the segment routing header.

28. The apparatus according to any of claims 21-27, wherein the mapping further comprises mapping an error code and an end marker to the segment routing internet protocol header via the time-length-value field.

29. The apparatus according to any of claims 21-28, wherein the mapping further comprises mapping a transfer protocol data unit (T-PDU) of the GTP-U to the segment routing internet protocol header via the time-length-value

field.

30. An apparatus, comprising:
at least one processor; and
at least one memory comprising computer program code,
the at least one memory and the computer program code are configured, with the at least one processor to cause the apparatus at least to
receive, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and comprising a data packet of a user equipment,
extract data from the GTP-U extension header by executing a segment identifier mobility function; and
forward the GTP-U extension header to a data network.

31. The apparatus according to claim 30, wherein extracting the data comprises extracting GTP-U related content from the GTP-U extension header in the segment routing internet protocol header.

32. The apparatus according to claims 30 or 31, wherein extracting the data comprises extracting a transfer protocol data unit (T-PDU) of GTP-U related content from the GTP-U extension header in the segment routing internet protocol header.

33. The apparatus according to any of claims 30-32, wherein the at least one memory and the computer program code are further configured, with the at least one processor to cause the apparatus at least to process the extracted GTP-U related content as per the GTP-U extension header.

34. The apparatus according to any of claims 30-33, wherein the

forwarding comprises forwarding the data packet according to local policies.

35. The apparatus according to any of claims 30-34, wherein the data packet is forwarded to the data network according to an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier located in a time-length-value field of the segment routing internet protocol header.

36. The apparatus according to any of claims 30-35, wherein a transfer protocol data unit comprises the GTP-U extension header in a segment routing internet protocol header.

37. The apparatus according to any of claims 30-36, wherein the segment routing internet protocol header carries control information.

38. The apparatus according to any of claims 30-37, wherein the GTP-U extension header is one of a radio access network container type, an Xw radio access network container type, a new radio access network container type, or a packet data unit session container type.

39. The apparatus according to any of claims 30-38, wherein the GTP-U extension header is forwarded to the data network according to an application identifier and a general packet radio service tunneling protocol user plane tunnel endpoint identifier located in the GTP-U extension header.

40. The apparatus according to any of claims 30-39, wherein the GTP-U extension header is received in a segment routing internet protocol environment.

41. An apparatus, comprising:

means for receiving a data packet from a user equipment;

means for encapsulating the data packet into a general packet radio service tunneling protocol user plane (GTP-U) extension header;

means for mapping the GTP-U extension header to a segment routing internet protocol via a time-length-value field; and

means for forwarding the GTP-U extension header along with the data packet to a user plane function element,

wherein the mapping means comprises means for mapping the GTP-U extension header to an encoding scheme of the segment routing internet protocol using the time-length-value field.

42. An apparatus, comprising:

means for receiving, from a network element, a general packet radio service tunneling protocol user plane (GTP-U) extension header that is mapped to a segment routing internet protocol header, and comprising a data packet of a user equipment,

means for extracting data from the GTP-U extension header by executing a segment identifier mobility function; and

means for forwarding the GTP-U extension header to a data network.

43. A non-transitory computer readable medium comprising program instructions stored thereon for performing the method according to any of claims 1-20.

44. An apparatus comprising circuitry configured to cause the apparatus to perform a process according to any of claims 1-20.

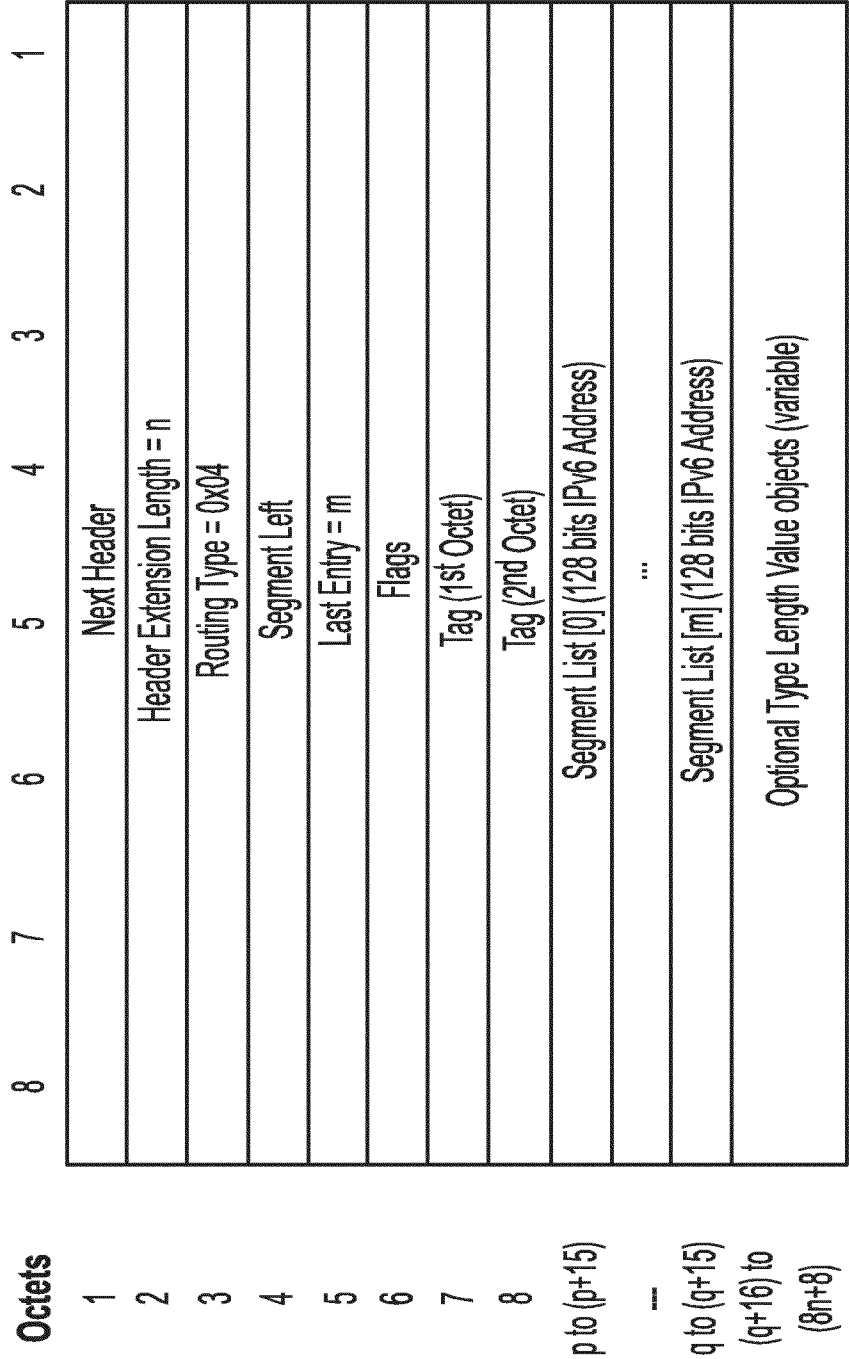


FIG. 1

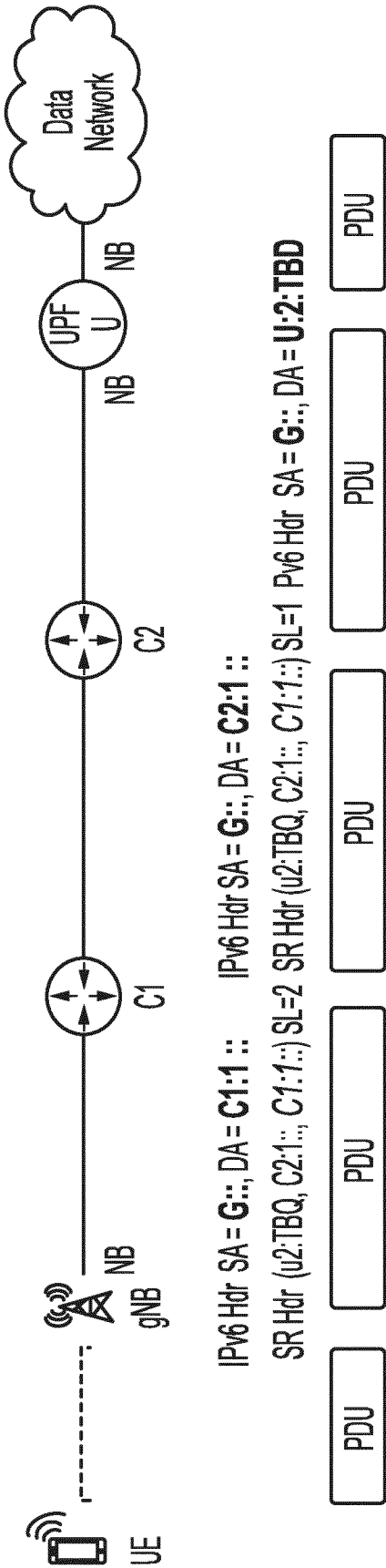


FIG. 2

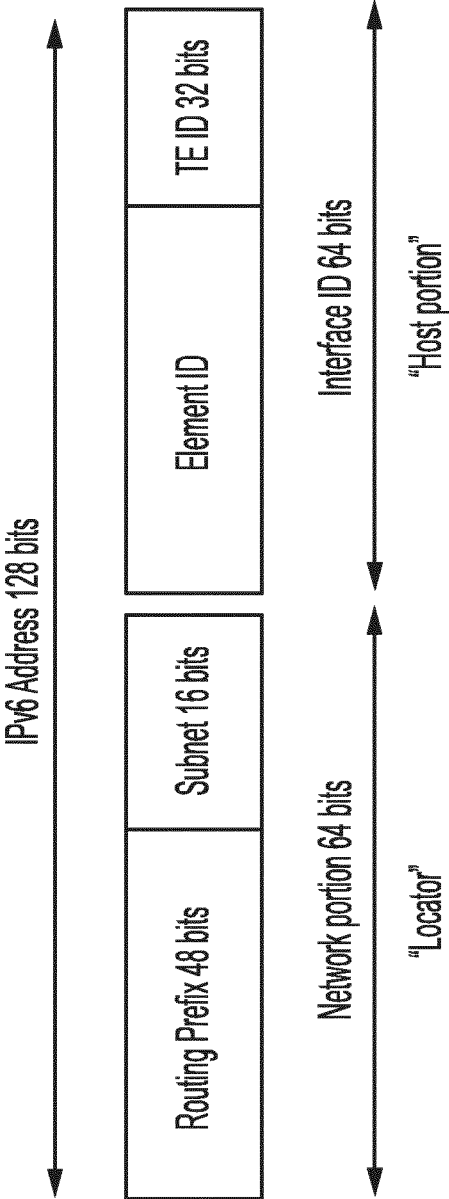


FIG. 3

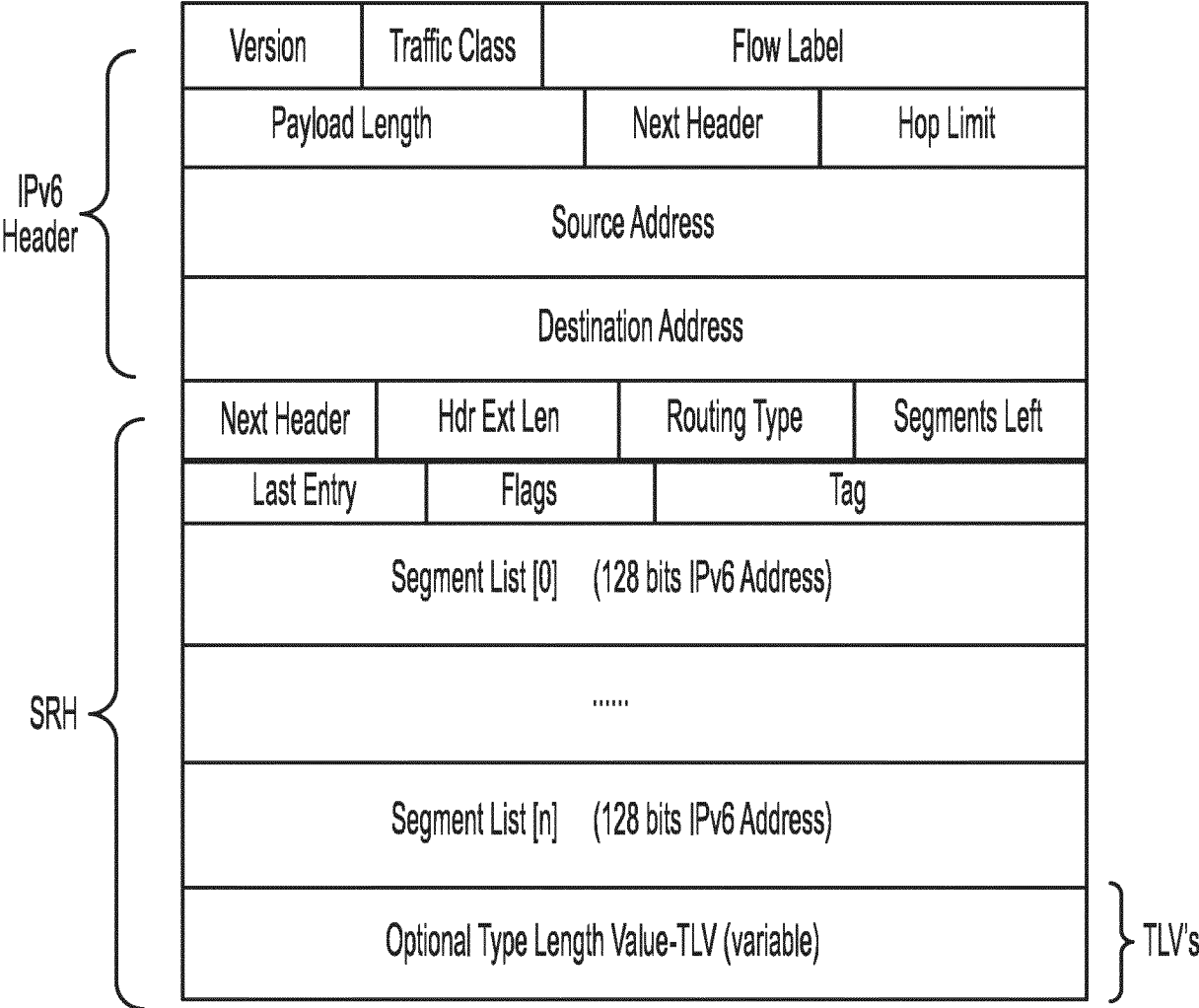
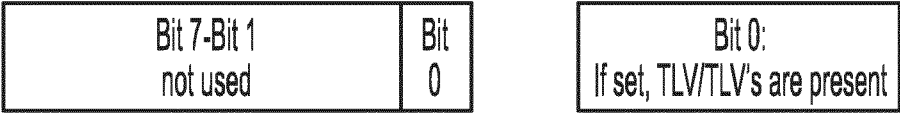


FIG. 4

SRH Flags



GTP-U TLV:

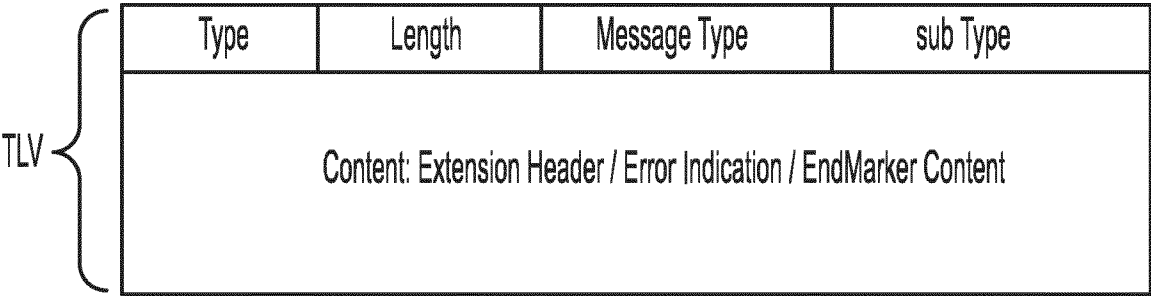


FIG. 4 CONT.

	Suggested Value	Description
1		Ingress Node TLV
2		Egress Node TLV
3		Opaque Container TLV
4		Padding TLV
5		HMAC TLV
6		NSH Carrier TLV This document
7		GTP-U TLV

FIG. 5

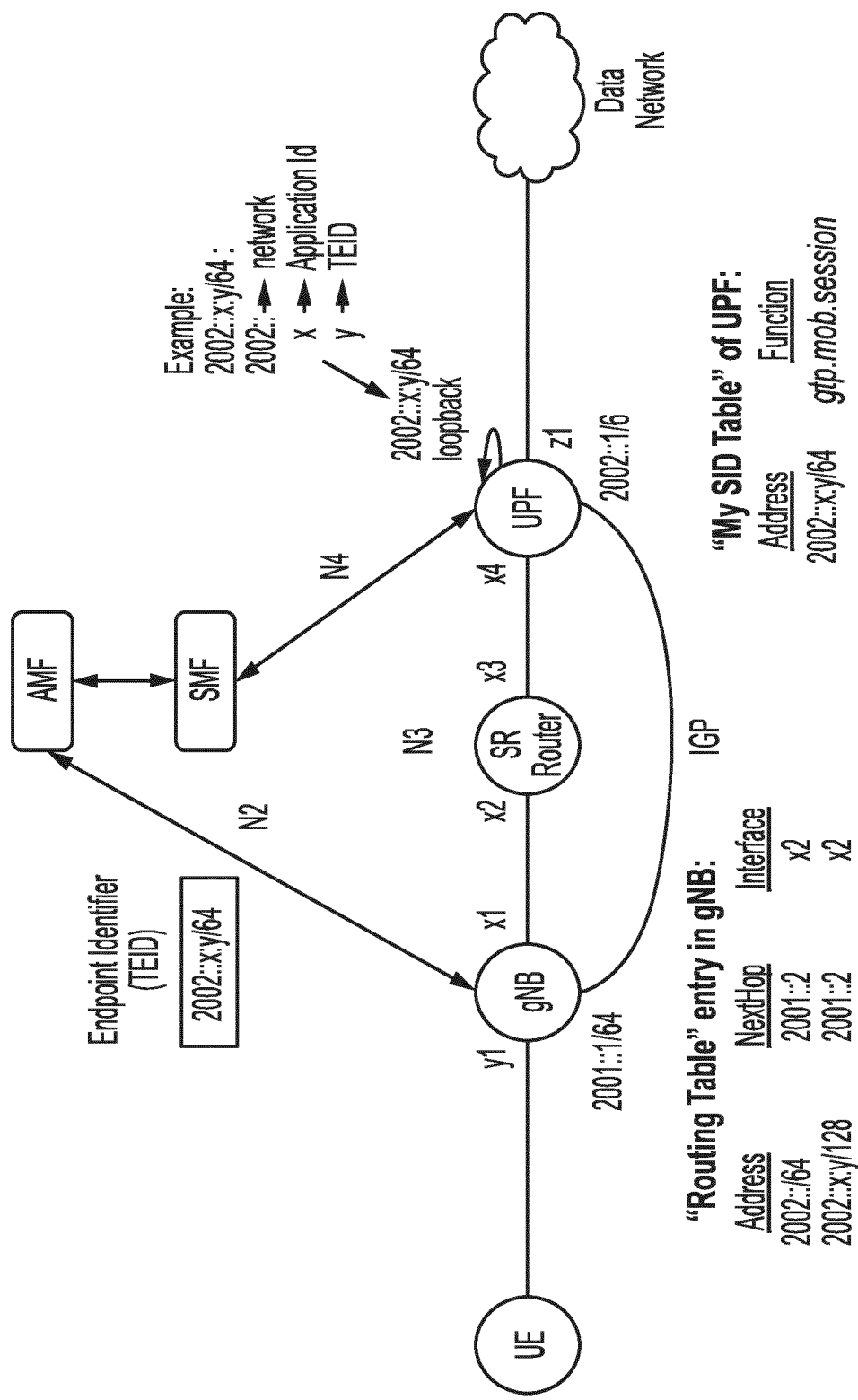


FIG. 6

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gtp.mob.session (new function) :

```
IF NH === (SRH)
  IF NH=SRH and SL == 0           ;; Ref1
    store TEID in variable new TEID
    Extract data from TLV's of SRH if any.
    Process the packet locally.
ELSE
  Process the packet locally
```

Ref1: The **gtp.mob.session** SID must always be the last SID in case of SRH.

FIG. 7

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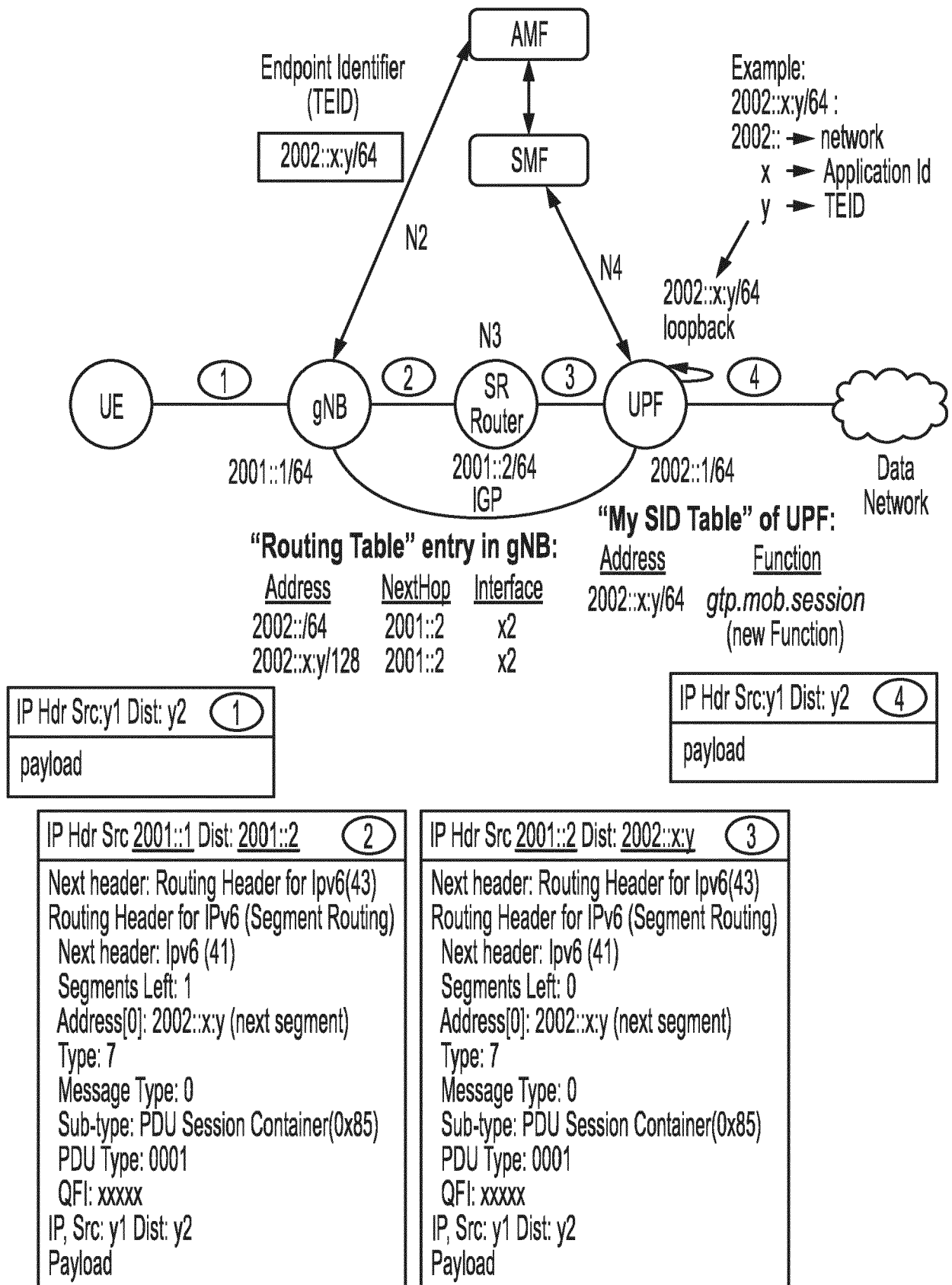


FIG. 8

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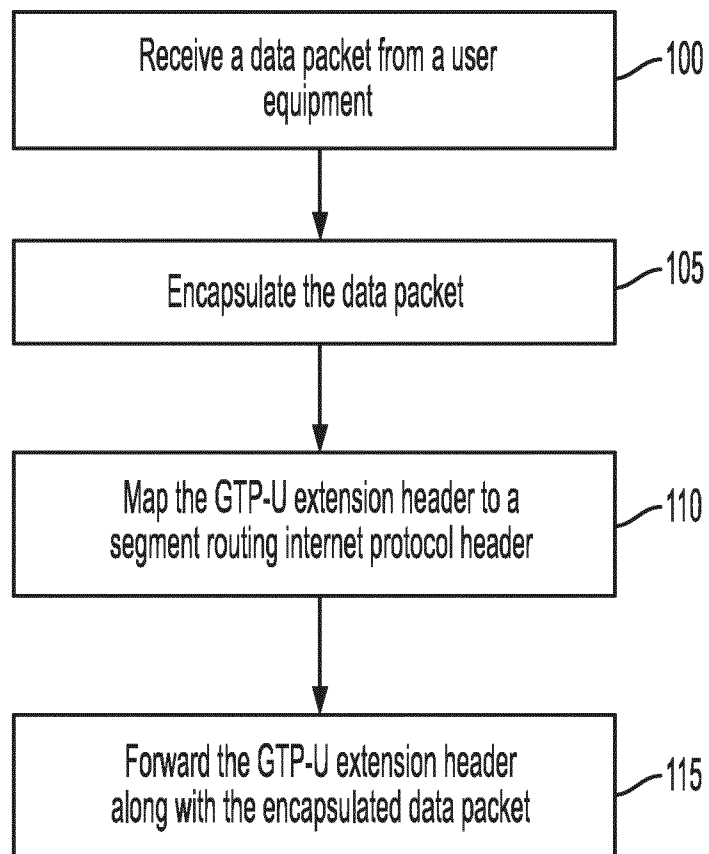


FIG. 9

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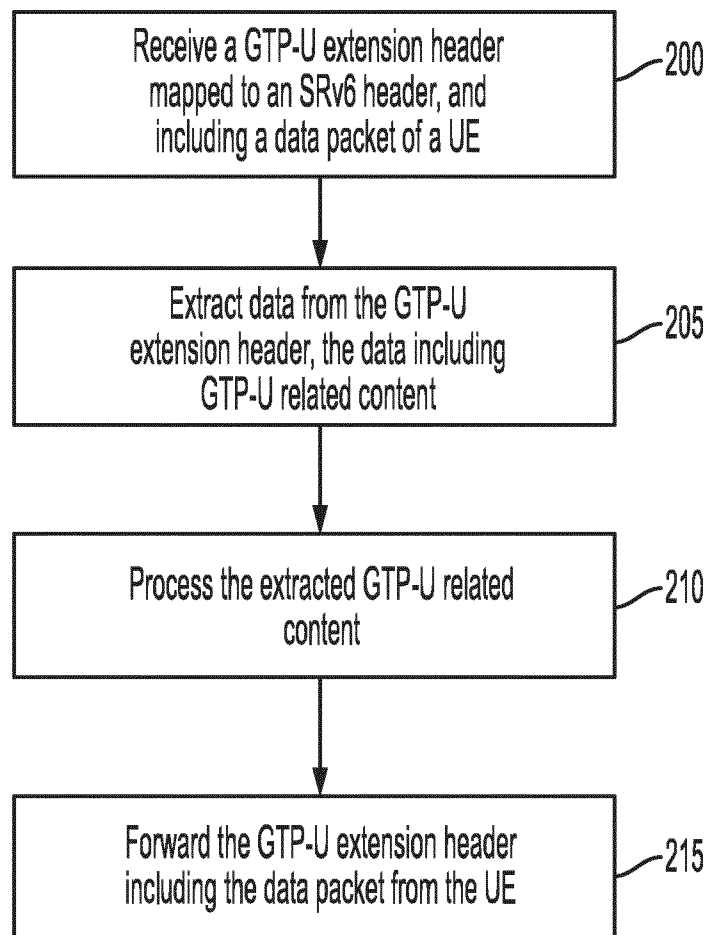


FIG. 10

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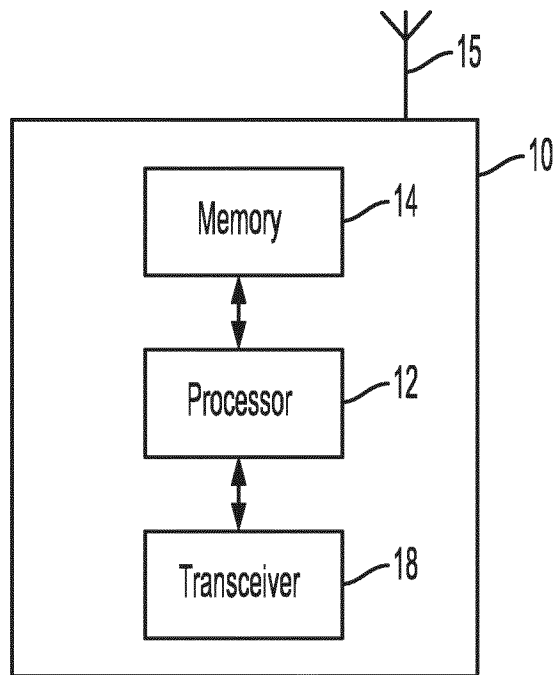


FIG. 11A

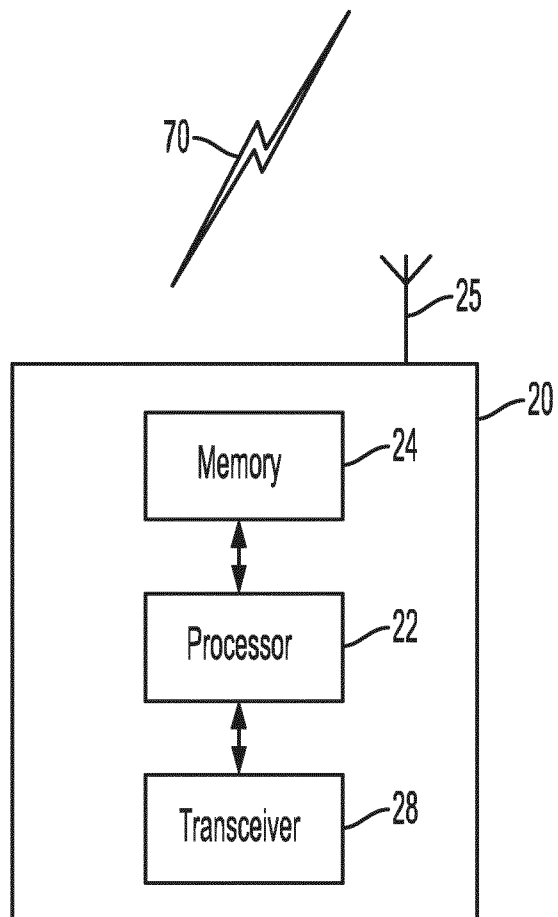


FIG. 11B

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End.M.GTP6.E:

1. IF NH=SRH & SL = 1 THEN ;; Note 1
2. decrement SL
3. store SRH[SL] in variable new_DA
4. store TEID in variable new_TEID ;; Note 2
5. store extension headers, error Indication and end Marker if any in SRv6 SRH TLV's.
6. pop IP header and all its extension headers
7. push new IPv6 header and GTP-U header
8. set IPv6 DA to new_DA
9. set GTP_TEID to new_TEID
10. set extension headers, error Indication and end Marker if any to GTP-U header.
11. lookup the new_DA and forward the packet accordingly
12. ELSE
13. Drop the packet

Note 1: An End.M.GTP6.E SID MUST always be the penultimate SID.

Note 2: TEID is extracted from the argument space of the current SID. If valid TEID is not available in argument space of SID, SRv6 TLV's needs to be checked.

FIG. 12A**End.M.GTP6.D:**

1. IF NH=UDP & UDP_PORT = GTP THEN
2. pop the IPv6, UDP and GTP headers
3. push a new IPv6 header with its own SRH <S2, S3> ;Ref1
4. set the outer IPv6 SA to A
5. set the outer IPv6 DA to S1
6. forward according to the S1 segment of the SRv6 Policy
7. ELSE
8. Drop the packet

Ref1: Mapping of GTP-U T-PDU, extension headers, error Indication and end Marker to SRv6 TLV is handled as part of this step.

FIG. 12B

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End.M.GTP4.E:

1. IF NH=SRH & SL = 0 THEN
2. store SRH[0] in buffer S
3. pop the IPv6 header and its extension headers
4. push UDP/GTP headers with GTP TEID from S
5. If GTP-U extension headers, error Indication and/or end Marker is part of SRv6 SRH TLV, push GTP headers with respective fields from S.
6. push outer IPv4 header with SA, DA from S
7. ELSE
8. Drop the packet

FIG. 12C

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/062032

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/46 H04L12/723 H04L12/741
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Study on User Plane Protocol in 5GC. (Release 16)", 3GPP STANDARD; TECHNICAL REPORT; 3GPP TR 29.892, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. CT WG4, no. V1.1.0, 30 April 2019 (2019-04-30), pages 1-47, XP051753785, [retrieved on 2019-04-30]	1-9, 21-29, 41,43,44
Y	6.2 Segment Routing IPv6 (SRv6); page 20 - page 27 ----- -/-	15,35



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 September 2020

Date of mailing of the international search report

05/10/2020

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/062032

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>MATSUSHITA SOFTBANK C FILSFILS M KOHNO P CAMARILLO CISCO SYSTEMS S ET AL: "Segment Routing IPv6 for Mobile User Plane; draft-ietf-dmm-srv6-mobile-uplane-04.txt", SEGMENT ROUTING IPV6 FOR MOBILE USER PLANE; DRAFT-IETF-DMM-SRV6-MOBILE-UPLANE-04.TXT; INTERNET-DRAFT: DMM WORKING GROUP, INTERNET ENGINEERING TASK FORCE, IETF; STANDARDWORKINGDRAFT, INTERNET SOCIETY (</p> <p>,</p> <p>no. 4 11 March 2019 (2019-03-11), pages 1-28, XP015131799, Retrieved from the Internet: URL:https://tools.ietf.org/html/draft-ietf -dmm-srv6-mobile-uplane-04 [retrieved on 2019-03-11] page 7 - page 13 page 18 - page 21</p> <p>-----</p>	<p>1-9, 21-29, 41,43,44</p>
X	<p>SOFTBANK CORP ET AL: "Pseudo-CR on UP Path Validation", 3GPP DRAFT; C4-191513-WAS-C4-191208-UP-PATH-VALIDATION , 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>,</p> <p>vol. CT WG4, no. Xi'an, P.R.China; 20190408 - 20190412 12 April 2019 (2019-04-12), XP051706767, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fct/WG4%5 Fprotocollars%5Fex%2DCN4/TSGCT4%5F90%5FXia n/Docs/C4%2D191513%2Ezip [retrieved on 2019-04-12]</p>	<p>10-14, 16-20, 30-34, 36-40, 42-44</p>
Y	<p>the whole document</p> <p>-----</p> <p>-/--</p>	<p>15,35</p>

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/062032

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	<p>NOKIA ET AL: "Pseudo-CR on Conclusions for User Plane in 5GC", 3GPP DRAFT; C4-193507_29892-PCR-CONCLUSIONS, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. CT WG4, no. Wroclaw, Poland; 20190826 - 20190830 22 August 2019 (2019-08-22), XP051764297, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ct/WG4_protocollars_ex-CN4/TSGCT4_93_Wroclaw/Docs/C4-193507.zip [retrieved on 2019-08-22] the whole document</p> <p style="text-align: center;">-----</p>	<p>1,10,21, 30,41-44</p>

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2020/062032

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-9, 21-29, 41(completely); 43, 44(partially)

Method, corresponding apparatus and computer readable medium, comprising: (1.1) receiving a data packet from a user equipment; (1.2) encapsulating the data packet into a GTP-U extension header; (1.3) mapping the GTP-U extension header to a segment routing internet protocol (SR) via a time-length-value (TLV) field; and (1.4) forwarding the GTP-U extension header along with the data packet to a user plane function element, wherein the (1.3.1) mapping comprises mapping the GTP-U extension header to an encoding scheme of the SR using the TLV field.

2. claims: 10-20, 30-40, 42(completely); 43, 44(partially)

Method, corresponding apparatus and computer readable medium, comprising: (2.1) receiving, from a network element, a GTP-U extension header that is mapped to a SR protocol header, and comprising a data packet of a user equipment, (2.2) extracting data from the GTP-U extension header by executing a segment identifier mobility function; and (2.3) forwarding the GTP-U extension header to a data network.
