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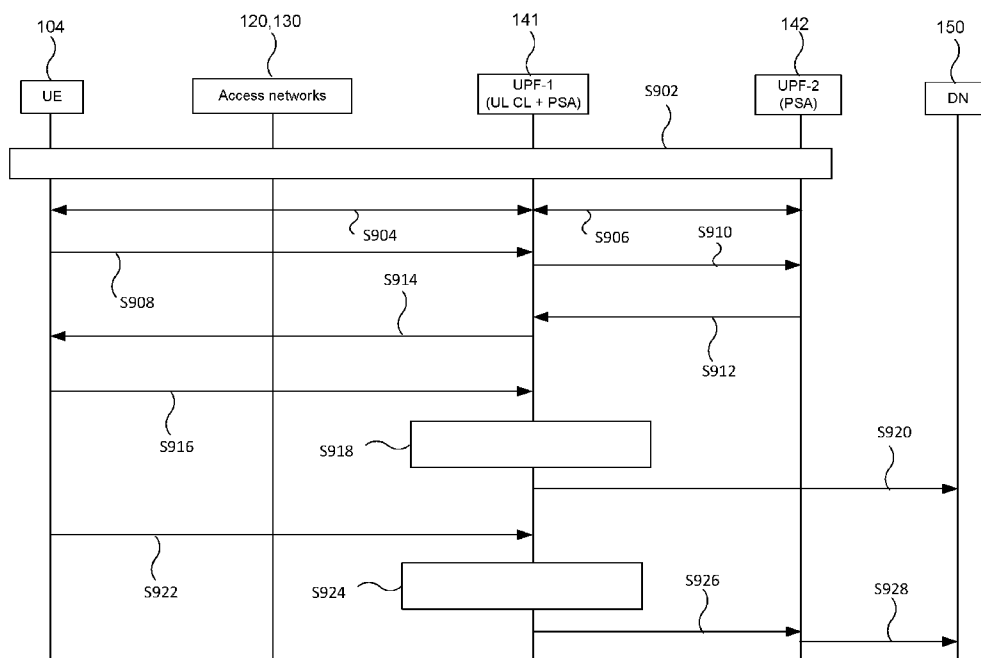


Figure 9

(57) Abstract: Various aspects of the present disclosure relate to a user plane function (UPF) network entity, comprising: at least one memory; and processors) coupled with the memory and configured to cause the UPF network entity to: establish a multi-access communication session with a user equipment (UE) and a further UPF network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receive a message via a first access path for transmission to the data network; determine whether to transmit the message directly to the data network or to the data network via the further UPF network entity; and in response to a determination to transmit the message via the further UPF network entity, transmit the message to the further UPF network entity via a second access path having the same access path type as the first access path.

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MULTI-ACCESS COMMUNICATION SESSION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a multi-access communication session. In particular, the present disclosure relates to a multi-access communication session involving multiple User-Plane Functions (UPFs) each operating as a protocol data unit (PDU) session anchor.

BACKGROUND

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

[0003] In a 5G network, a PDU (Protocol Data Unit) Session is a logical connection which enables the flow of data packets between a 5G user equipment (UE) and a data network (DN) via the 5G network infrastructure. When a PDU Session is established, the 5G network creates a data path for it and configures the elements in the data path (aka user-plane functions) to provide the necessary Quality-of-Service (QoS) and routing behavior. The elements in the data path of the PDU Session comprise the UE, radio network elements and one or more User-Plane Function network entities (UPFs) in the core network. Typically, one of these UPFs operates as “PDU Session Anchor” (PSA) and it serves as the fixed point for transferring data packets to and from the data network (DN) via an N6 interface. A PDU

Session can support different types of data traffic such as Ethernet, Unstructured, and IPv4 or IPv6.

SUMMARY

[0004] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[0005] Some implementations of the method and apparatuses described herein may include a user plane function network entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the user plane function network entity to: establish a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receive a data message via a first access path for transmission to the data network; determine whether to transmit the data message directly to the data network or to the data network via the further user plane function network entity; and in response to a determination to transmit the data message to the data network via the further user plane function network entity, transmit the data message to the further user plane function network entity via a second access path having the same access path type as the first access path.

[0006] The at least one processor may be configured to cause the user plane function network entity to use forward-action rules to perform the determination.

[0007] The at least one processor may be configured to cause the user plane function network entity to establish a second set of one or more multipath QUIC connections with the further user plane function network entity in response to establishing a first set of one or more multipath QUIC connections with the UE, wherein each multipath QUIC connection in the second set is associated with a respective multipath QUIC connection in the first set.

[0008] The at least one processor may be configured to cause the user plane function network entity to: establish a first set of one or more communication tunnels with the UE, each communication tunnel in the first set using a multipath QUIC connection in the first set of one or more multipath QUIC connections, and establish a second set of one or more communication tunnels with the further user plane function network entity, each communication tunnel in the second set using a multipath QUIC connection in the second set of one or more multipath QUIC connections, wherein each communication tunnel in the second set is associated with a communication tunnel in the first set.

[0009] The at least one processor may be configured to cause the user plane function network entity to: receive the data message via a first communication tunnel in the first set of one or more communication tunnels; and transmit the data message to the further user plane function network entity via a second communication tunnel in the second set of one or more communication tunnels that is associated with the first communication tunnel.

[0010] The at least one processor may be configured to cause the user plane function network entity to: receive downlink data from the further user plane function network entity via a second communication tunnel in the second set of one or more communication tunnels; and transmit the downlink data to the UE via a first communication tunnel in the first set of one or more communication tunnels that is associated with the second communication tunnel.

[0011] The at least one processor may be configured to cause the network entity to select an access path of the plurality of access paths, for routing downlink data received from the further user plane function network entity to the UE, using multi-access rules.

[0012] The at least one processor may be configured to cause the user plane function network entity to: in response to a determination to transmit the data message directly to the data network, transmit the data message to the data network.

[0013] Some implementations of the method and apparatuses described herein may include a method performed by a user plane function network entity, the method comprising: establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receiving a data message via a first access path for transmission to the data network; determining whether to transmit the data message directly to the data network or to the data network via the further user plane function network entity; and in response to determining to transmit the data message to the data network via the further user plane function network entity, transmitting the data message to the further user plane function network entity via a second access path having the same access path type as the first access path.

[0014] The method may further comprise using forward-action rules to perform the determining.

[0015] The method may further comprise: establishing a second set of one or more multipath QUIC connections with the further user plane function network entity in response to establishing a first set of one or more multipath QUIC connections with the UE, wherein each multipath QUIC connection in the second set is associated with a respective multipath QUIC connection in the first set.

[0016] The method may further comprise establishing a first set of one or more communication tunnels with the UE, each communication tunnel in the first set using a multipath QUIC connection in the first set of one or more multipath QUIC connections, and receiving the data message via a first communication tunnel in the first set of communication tunnels.

[0017] The method may further comprise: establishing a second set of one or more communication tunnels with the further user plane function network entity, each communication tunnel in the second set using a multipath QUIC connection in the second set of one or more multipath QUIC connections, wherein each communication tunnel in the

second set is associated with a communication tunnel in the first set, and transmitting the data message to the further user plane function network entity via a second communication tunnel associated with the first communication tunnel.

[0018] The method may further comprise: in response to determining to transmit the data message directly to the data network, transmitting the data message to the data network.

[0019] Some implementations of the method and apparatuses described herein may include a user plane function network entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the user plane function network entity to: establish a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receive a TCP message from the UE requesting a TCP connection to a device in the data network; determine to establish the TCP connection directly with the device in the data network; and in response to said determination, establish a first TCP connection with the UE and establish a second TCP connection with the device, wherein the first TCP connection supports multipath communication over the plurality of access paths.

[0020] The at least one processor may be configured to cause the user plane function network entity to use forward-action rules to perform the determination.

[0021] The TCP message may comprise an identifier indicating that the UE supports multipath TCP, and identifiers associated with the device.

[0022] Some implementations of the method and apparatuses described herein may include a user plane function network entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the user plane function network entity to: establish a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receive a message from the UE requesting a TCP connection to a device in the data network; determine to establish the TCP connection to the device in the data network via the further user plane function network entity; and in response to said determination, establish a first multipath TCP connection with the user equipment and

an associated second multipath TCP connection with the further user plane function network entity, wherein the first and the second multipath TCP connections support multipath communication over the plurality of access paths.

[0023] The at least one processor may be configured to cause the user plane function network entity to use forward-action rules to perform the determination.

[0024] The TCP message may comprise an identifier indicating that the UE supports multipath TCP, and identifiers associated with the device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Figure 1 illustrates a single access PDU session.

[0026] Figure 2 illustrates a multi-access PDU session with a single PSA.

[0027] Figure 3 illustrates the protocol layers involved in a multi-access PDU session with a single PSA.

[0028] Figure 4 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0029] Figure 5 illustrates an example of a general architecture for ATSSS that is useful for understanding aspects of the present disclosure.

[0030] Figure 6 illustrates the protocol layers involved in a multi-access PDU session with multiple PSAs in accordance with aspects of the present disclosure.

[0031] Figure 7 illustrates an example of a process to establish a multi-access PDU Session with multiple PSAs in accordance with aspects of the present disclosure.

[0032] Figure 8 illustrates an example of a process to add a PSA to an existing multi-access PDU Session in accordance with aspects of the present disclosure.

[0033] Figure 9 illustrates an example of user plane data flow with two PSAs when MPQUIC steering functionality is applied in a multi-access PDU Session in accordance with aspects of the present disclosure.

[0034] Figure 10 illustrates the protocol layers involved in the user-plane communication via a multi-access PDU Session with two PSAs in the example where the MPQUIC steering functionality is applied in accordance with aspects of the present disclosure.

[0035] Figure 11 illustrates an example of user plane data flow with two PSAs when MPTCP steering functionality is applied in the multi-access PDU Session in accordance with aspects of the present disclosure.

[0036] Figure 12 illustrates an example of a processor 1200 in accordance with aspects of the present disclosure.

[0037] Figure 13 illustrates an example of a network equipment (NE) 1300 in accordance with aspects of the present disclosure.

[0038] Figure 14 illustrate a flowcharts of method performed by a NE (e.g. a SMF) in accordance with aspects of the present disclosure.

[0039] Figure 15 illustrate a flowcharts of method performed by a NE (e.g. a SMF) in accordance with aspects of the present disclosure.

[0040] Figure 16 illustrate a flowcharts of method performed by a NE (e.g. a UMF) in accordance with aspects of the present disclosure.

[0041] Figure 17 illustrate a flowcharts of method performed by a NE (e.g. a UMF) in accordance with aspects of the present disclosure.

[0042] Figure 18 illustrate a flowcharts of method performed by a NE (e.g. a UMF) in accordance with aspects of the present disclosure

DETAILED DESCRIPTION

[0043] In certain scenarios, a PDU Session can have multiple PSAs, i.e., multiple UPFs that transfer data traffic to and from a data network via *different* N6 interfaces. The use of multiple PSAs can optimize the routing of data traffic and can facilitate access to both edge-computing (local) services and traditional centralized (remote) services using the shortest data paths.

[0044] The data path of an example PDU Session with two PSAs is shown in Figure 1. This data path provides IP connectivity between the UE and a first user plane function network entity (UPF-1) and between UPF-1 and a second user plane function network entity (UPF-2). During the establishment of the PDU Session, a Session Management Function network entity (SMF) responsible for the session decides whether one or more PSAs should be included in the data path. If only one PSA is initially included (i.e., UPF-2), the SMF may later add an additional PSA in the data path (i.e., UPF-1). Note that UPF-1 does not only provide PSA functionality, but it also operates as an “uplink classifier” (UL CL). It is responsible for determining the routing of uplink data traffic, deciding whether it should be sent to the Data Network (DN) via its local N6 interface or forwarded to UPF-1. These routing choices are made based on guidelines provided by the SMF.

[0045] The PDU Session shown in Figure 1 is a *single-access* PDU Session because the UE utilizes a single access network for data communication; either a non-3GPP access network (e.g., WiFi), or a 3GPP access network (e.g., NR-RAN). In this case, the PDU Session provides a single data path between the UE and a 5G network.

[0046] 5G networks also support *multi-access* PDU Sessions that offer multiple different data paths between the UE and the 5G network. An example of such session is shown in Figure 2, where data communication is supported via multiple access networks, typically one non-3GPP access network and one or more 3GPP access networks. The capability to support multi-access PDU Sessions was introduced in the context of the Access Traffic Steering, Switching and Splitting (ATSSS) feature.

[0047] The ATSSS feature, as defined in the Third Generation Partnership Project (3GPP) Rel-18 specifications, provides enhanced data communication capabilities by allowing a UE to utilize multiple access paths simultaneously. This is achieved by establishing a multi-access communication session (referred to in the 3GPP specifications as Multiaccess Packet Data Unit (MA PDU) Session) that supports two access paths, one 3GPP access path, using an access network defined by 3GPP, such a NG-RAN, and one non-3GPP access path, using an access network not defined by 3GPP, such as Wi-Fi. Every data packet that should be transmitted via the multi-access communication session is transmitted either over the 3GPP access path or over the non-3GPP access path, according to multi-access rules,

which are provided to the UE and to a User Plane Function (UPF) during the establishment of the multi-access communication session.

[0048] A problem is that contrary to a single-access PDU Session, a multi-access (MA) PDU Session cannot support multiple PSAs. As illustrated in Figure 2, although an MA PDU Session may have multiple UPFs, only one of these UPFs (e.g. UPF-2 in Figure 2) can provide the PSA functionality and can route data traffic to the DN. Other UPFs (e.g. UPF-1 in Figure 2) may be included in the data path but cannot route data to the DN via their own N6 interfaces. Therefore, a MA PDU Session currently defined cannot support simultaneous access to both edge-computing (local) services and traditional centralized (remote) services.

[0049] The root cause of this problem is explained with reference to Figure 3 which illustrates the protocol layers involved in a multi-access PDU session with a single PSA. In an MA PDU Session, the UE and the PSA implement special functionality, called steering functionality, that is required to enable the multipath communication. This steering functionality can be based on the QUIC protocol (as shown in Figure 3), or on the multipath TCP (MPTCP) protocol. It requires the UE to operate as a client and the PSA to operate as a proxy. In known techniques the steering functionality in the network can reside only in one UPF, so there can be only one proxy / PSA. Other UPFs may be included in the data path but they cannot operate as proxies / PSAs. They only relay the data traffic between the UE and the proxy.

[0050] To address the above problem, this disclosure proposes enhancements to the 5G network architecture that enables a MA PDU Session to have multiple PSAs, thus, making it feasible to simultaneously support (a) multipath communication between the UE and edge-computing (local) services in a DN and (b) multipath communication between the UE and traditional centralized (remote) services in the same DN.

[0051] Aspects of the present disclosure are described in the context of a wireless communications system.

[0052] Figure 4 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an

LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0053] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0054] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0055] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some

implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0056] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0057] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N2, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0058] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management function network entity (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0059] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N2, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0060] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0061] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0062] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0063] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0064] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless

communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0065] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0066] Figure 5 illustrates an example of a general architecture 200 for ATSSS that is useful for understanding aspects of the present disclosure. The general architecture 200 may be implemented in the context of Figure 4.

[0067] A remote unit 104 (i.e., a UE) is shown that has established a multi-access data communication session (MA PDU Session) with a CN network 106 (e.g. a 5G core network) using two types of access networks: (a) a 3GPP access network 120 and (b) a non-3GPP access network 130. The first type of access network 120 uses a 3GPP-defined type of wireless communication (e.g., NG-RAN comprising the cellular base unit 102a), while the second type of access network 130 uses a non-3GPP-defined type of wireless communication (e.g., a wireless local area network (WLAN)/WiFi, indicated by the access point 102b). The non-3GPP access network 130 interfaces with the 5G core network via an interworking function 133 (N3IWF or TNGF) using the standard N2/N3 interfaces. The multi-access data communication session may support additional access network types (such as non-terrestrial accesses), which are not shown.

[0068] The CN network 106 comprises a first user plane function network entity (UPF-1) 141, a second user plane function network entity (UPF-2) 142, an AMF 143, an SMF 145, a policy control function network entity (PCF) 147 and a Unified Data Management network entity (UDM) 149.

[0069] The first type of access network 120 uses a 3GPP-defined type of wireless communication (e.g., NG-RAN comprising the cellular base unit 102a), while the second type of access network 130 uses a non-3GPP-defined type of wireless communication (e.g., a wireless local area network (WLAN)/WiFi).

[0070] During the multi-access data communication session (MA PDU Session), a multi-access data connection 148 is established between the UE 104 and UPF-1 141 in the CN 106, which can support data communication using multiple access types simultaneously. The multi-access data connection 148 supports two user-plane connections: one user-plane connection using communication over 3GPP access 125 and another user-plane connection using communication over non-3GPP access 135. In general, a MA PDU Session may have two or more user-plane connections, each one using communication over a different type of access network. Each user-plane connection creates an access path between the UE 104 and the UPF-1 141.

[0071] During the establishment of the MA PDU Session 148, the PCF 147 creates steering rules for the Uplink (UL) traffic and steering rules for the Downlink (DL) traffic, which are forwarded to the UE 104 and to UPF-1 141, UPF-2 142, respectively. The UL steering rules 108 are called ATSSS rules, and the DL steering rules 109 are called Multiaccess Access Rules (MAR). The steering rules specify how the UL traffic and how the DL traffic of the MA PDU Session is to be routed across the access paths of the MA PDU Session. The UPF-1 141 is provided also with Forward Access Rules (FAR), which specify the uplink traffic that should be routed locally by UPF-1 141 (via its N6 interface) and the uplink traffic that should be forwarded to UPF-2 142.

[0072] The MA PDU Session enables the UE 104 to support multipath communication with a local host device 153 in a data network 150 and multipath communication with a remote host device 155 in the data network 150. The local host device 153 may be located closer to the UE 104 than to the remote host device 155. For example, the local host device 153 may be an edge-computing computing device, whereas the remote host device 155 may be a centralized computing device.

[0073] Embodiments of the present disclosure enable MA PDU Sessions with multiple PSAs. Such MA PDU Sessions can route data traffic to a DN via multiple N6 interfaces and, thus, enable (a) multi-access communication between the UE and edge-computing (local)

services and (b) multipath communication between the UE and traditional centralized (remote) services.

[0074] Figure 6 illustrates the protocol layers involved in a multi-access PDU session with multiple PSAs. As illustrated in Figure 6, in embodiments of the present disclosure, not only UPF-2, but also UPF-1 is enabled to function as a proxy and provide PSA functionality. Both UPFs implement a steering functionality, for example, the QUIC-based steering functionality (as shown in Figure 6), or the MPTCP-based steering functionality. The UE 104 is configured to send all data traffic of the MA PDU Session to the proxy (otherwise referred to herein as a proxy function) in UPF-1 141. In turn, UPF-1 141 decides whether the received data traffic should be routed to the DN 150 via its local N6 interface, or whether it should be forwarded to the next proxy in UPF-2 142. The UPF-1 141 makes these decisions based on information received from a SMF 145, which enable UPF-1 141 to operate also as an uplink classifier (UL CL). In addition, UPF-1 141 is configured by the SMF 145 to know information about the proxy in UPF-2 142, such as its IP address, ports, etc.

[0075] As further discussed below, in examples whereby QUIC-based steering functionality is implemented (as shown in Figure 6), the UE 104 establishes a number of multipath QUIC connections 602 with UPF-1 and UPF-1 establishes the same number of multipath QUIC connections 604 with UPF-2. Each of these multipath QUIC connections carries the traffic of a particular QoS flow. When UPF-1 141 receives data traffic from UE via a multipath QUIC connection 602, it decides to either send it to the DN 150 via its local N6 interface, or to forward it to UPF-2 via an associated multipath QUIC connection 604.

[0076] As further discussed below, in examples whereby MPTCP-based steering functionality is implemented (not shown in Figure 6) the UE 104 establishes a MPTCP connection with UPF-1 141 for every TCP flow it wants to transmit via the MA PDU Session. If UPF-1 141 decides to forward a TCP flow to UPF-2 142, the UPF-1 141 establishes another MPTCP connection with UPF-2 142 and relays the TCP flow between these MPTCP connections. If UPF-1 141 decides to forward a TCP flow to its local N6 interface, then the MPTCP connection with UPF-2 142 is not required.

[0077] From the perspective of the UE 104, there is only one proxy (UPF-1). The UE 104 does not have visibility to, and does not need to, directly communicate with the proxy in UPF-2 142. The UE 104 does not need to know whether the MA PDU Session has one or

multiple PSAs, hence, the UE behavior is not impacted by the enhancements in this disclosure.

[0078] Below we present the procedures that enable a MA PDU Session with multiple PSAs. These procedures are split into (i) control-plane procedures, which define the exchange of signaling messages required to set up an MA PDU Session with multiple PSAs; and (ii) user-plane procedures, which define the exchange of data traffic after a MA PDU Session with multiple PSAs has been established.

Control-plane procedures

[0079] Figure 7 illustrates a process 700 to establish a MA PDU Session with multiple PSAs (i.e. multiple UPFs).

[0080] At step S702, the UE 104 registers with the 5G core network 106 over 3GPP access and/or over non-3GPP access using its 5GS credentials, stored in a USIM module. The regular registration procedure is carried out. After the 5G registration procedure an N1 connection is established over each access, and the UE 104 may securely exchange NAS messages with the AMF 143.

[0081] At step S704, the UE 104 decides to establish a MA PDU Session. For this purpose, the UE 104 transmits via the N1 connection an UL NAS Transport message to the AMF 143. This message contains a PDU Session Establishment Request message to be forwarded to an SMF 145 comprising an MA PDU Session indication which indicates to AMF 143 this is a request for a multi-access (MA) PDU Session. Within a “5GSM capability” element in the PDU Session Establishment request message, the UE 104 includes its ATSSS capabilities. For example, the UE 104 may include in the “5GSM capability” element that it supports traffic steering, switching, and splitting using the “MPQUIC-IP steering functionality” and/or the “MPTPC steering functionality”. At step S706, the access network that has been selected by the UE 104 to use for requesting the MA PDU Session (i.e. either the 3GPP access network 120 or the non-3GPP access network 130) forwards the UL NAS Transport message to the AMF 143 within a NGAP Uplink NAS Transport message.

[0082] In response to receiving the UL NAS Transport message from the UE 104, which indicates that an MA PDU Session is requested, the AMF 143 selects an SMF 145 and transmits at step S708 a Create SM Context Request message to SMF 145, according to

known techniques (see, e.g., 3GPP TS 23.502). This message encapsulates the PDU Session Establishment Request provided by the UE 104. That is, at step S708, the SMF 145 receives a message requesting establishment of a multi-access communication session that supports data transmission between the UE 104 and data network 150 over a plurality of access paths. In response, at step S710 the SMF 145 sends a Create SM Context Response to the AMF 143.

[0083] At step S712, the SMF 145 selects a PCF 147 and sends an SM Policy Control Create Request message to the PCF 147 for providing session management control information. This message contains the MA PDU Request indication and the ATSSS capabilities of the UE 104, which were received by SMF 145 within the “5GSM capability” element.

[0084] In response, at step S714 the PCF 147 creates policy information e.g. one or more Policy and Charging Control (PCC rules) with “MA PDU Session Control” information indicating how the uplink traffic and how the downlink traffic should be routed across the various access paths of the MA PDU Session. A PCC rule may contain a Service Data Flow (SDF) Detection element that identifies the traffic matching this rule and additional elements indicating how the matching traffic should be handled. One of these additional elements is the “MA PDU Session Control” element, which identifies how the matching traffic should be routed across the various access paths of the MA PDU Session. For creating the PCC rules, the PCF 147 takes into account the ATSSS capabilities of the UE 104 and the network policy.

[0085] At step S716, the PCF 147 returns a SM Policy Control Create Response message to SMF 145 including the created PCC rules with MA PDU Session Control, which should be applied for the MA PDU Session.

[0086] At step S718, the SMF 145 decides to select two PDU Session Anchors (PSAs) for the MA PDU Session, a first PSA and a second PSA. The SMF may decide that, for example, because it wants the UE to be able to reach local services, via the first PSA, and remote services, via the second PSA, within the same DN 150. The SMF 145 also selects an Uplink Classifier (UL CL), which will be receiving all uplink data flows from the UE 104 and will be forwarding each data flow either to the first PSA or to the second PSA. Since the PSA functionality and the UL CL functionality are typically implemented in a UPF, the SMF

145 typically selects two UPFs for the MA PDU Session. A first UPF (UPF-1) 141 implementing the UL CL functionality and the first PSA functionality and a second UPF (UPF-2) 142 implementing the second PSA functionality.

[0087] At step S719, based on the PCC rules received from PCF 147, the SMF 145 creates corresponding ATSSS rules for the UE 104, Multi-Access Rules (MAR) for UPF-2 142 and Multi-Access Rules (MAR) for UPF-1 141. The ATSSS rules indicate to the UE 104 how to route uplink data traffic across the available accesses of the MA PDU Session. The multi-access rules for UPF-2 indicate how UPF-2 should route the downlink data traffic arriving via its N6 interface across the available accesses of the MA PDU Session. Similarly, the multi-access rules for UPF-1 141 indicate how UPF-1 141 should route the downlink data traffic arriving via its N6 interface across the available accesses of the MA PDU Session. It is noted that when UPF-1 141 relays data traffic between the UE 104 and UPF-2 142, it does not take multi-access routing decisions, it just forwards the data traffic on the access type selected by the UE 104 or UPF-2 142.

[0088] At step S720, the SMF 145 also creates Forward Action Rules (FAR) for UPF-1 141. These rules are applied by the UL CL functionality in UPF-1 141 and indicate which uplink traffic should be forwarded to the N6 interface of UPF-1 (i.e., which traffic should not be relayed to UPF-2). The forward action rules may be specified in accordance with 3GPP specifications (see e.g., TS 29.244).

[0089] The SMF 145 creates a Packet Forwarding Control Protocol (PFCP) session (also known as N4 session) with UPF-2 142 by sending a PFCP Session Establishment Request message (also referred to herein as a first session establishment request message) at step S722 that contains the created MAR for UPF-2 142, the DN Name (DNN) and a Provide ATSSS Control Information element. The Provide ATSSS Control Information element indicates which ATSSS functionalities should be activated in UPF-2 142 and information about each one. For example, it may indicate that the MPTCP functionality is required using a Transport Converter type of proxy, or that the MPQUIC functionality is required using a *connect-udp* or a *connect-ip* type of proxy. It may also indicate that the PMF functionality is required and that access performance measurements should be taken per QoS flow, including the identifiers for these QoS flows.

[0090] The PFCP Session Establishment Request message transmitted at step S722 contains (e.g., within the Provide ATSSS Control Information element) a new indication that indicates to UPF-2 that the allocated ATSSS resources will be used by another proxy (in UPF-1), not by the UE 104. The message transmitted at step S722 requests information enabling UPF-1 141 to communicate with UPF-142. The indication included in the message transmitted at step S722 is needed by UPF-2, for example, to allocate the appropriate IP addresses and ports so that the other proxy (in UPF-1) will be able to communicate with the proxy in UPF-2.

[0091] The UPF-2 142 accepts the request and responds at step S724 by transmitting a PFCP Session Establishment Response message (also referred to herein as a first session establishment response message) to the SMF 145, which includes an ATSSS Control Parameters element that comprises information to enable UPF-1 141 to communicate with UPF-2 142. The ATSSS Control Parameters provides information about the ATSSS functionalities allocated in UPF-2 142.

[0092] At step S726, the SMF 145 transmits a PFCP Session Establishment Request message (also referred to herein as a second session establishment request message) to UPF-1 141, which will provide PSA functionality and the UL CL functionality. This message contains the created MAR rules for UPF-1 141, the created Forward Action Rules (FAR) for UPF-1 142, the DN Name (DNN) and the Provide ATSSS Control Information element. The Forward Action Rules (FAR) for UPF-1 141 indicate to UPF-1 141 which uplink traffic should be forwarded to its N6 interface (i.e., which traffic should not be relayed to UPF-2). The PFCP Session Establishment Request message transmitted at step S726 also contains a data element which includes the information needed by UPF-1 141 to communicate UPF-2 142 with the proxy in UPF-2. In particular, the UPF-1 implements a first proxy function, UPF-2 implements a second proxy function, and the first proxy function communicates with the second proxy function using the information provided in the second session establishment request. The first proxy function may comprise an MPTCP proxy and/or a MPQUIC proxy. Similarly, the second proxy function may comprise an MPTCP proxy and/or a MPQUIC proxy. The data element may be created by the SMF 145 from the ATSSS Control Parameters provided by UPF-2 142 in step 724. After receiving the data element, the UPF-1

141 knows the IP addresses, the ports, the proxy type, and other information needed to communicate with the second proxy function implemented in UPF-2 142.

[0093] The UPF-1 141 accepts the PFCP Session Establishment Request message transmitted at step S726 and responds by transmitting a PFCP Session Establishment Response message (also referred to herein as a second session establishment response) to the SMF 145 at step S728. The PFCP Session Establishment Response message includes its own ATSSS Control Parameters element that provides information about the ATSSS functionalities allocated in UPF-1 141. The information in the ATSSS Control Parameters element will be provided to UE 104 so that it will be able to communicate with the first proxy function implemented in UPF-1. The SMF 145 derives information, i.e. Proxy Information (UPF-1 Proxy Information), which enables the UE 104 to communicate with the UPF-1 141 from the ATSSS Control Parameters element of the PFCP Session Establishment Response message received at step S728. In one example, the UPF-1 Proxy Information contains the same parameters as those in the ATSSS Control Parameters element.

[0094] The ATSSS Control Parameters element provided by a UPF may contain:

MPTCP Parameters, if the MPTCP steering functionality is enabled for the MA PDU Session. It contains:

- a. MPTCP Address Information: (a) the IP address for the MPTCP proxy in the UPF, (b) the port number of the MPTCP proxy in the UPF, and the type of MPTCP proxy in the UPF (i.e., Transport Converter).
- b. MPTCP Link-Specific IP Addresses: One IP address that the UE should be using for transmission over 3GPP access and one IP address that the UE should be using for transmission over non-3GPP access. The UE uses these two IP addresses when transmitting data with MPTCP.

MPQUIC Parameters, if the MPQUIC steering functionality is enabled for the MA PDU Session. It contains:

- c. MPQUIC Address Information: (a) the IP address for the MPQUIC proxy in the UPF, (b) the port number of the MPQUIC proxy in the UPF, and the type of MPQUIC proxy in the UPF (i.e., connect-ip or connect-upd).
- d. MPQUIC Link-Specific IP Addresses: One IP address that the UE should be using for transmission over 3GPP access and one IP address that the UE should be using for

transmission over non-3GPP access. The UE uses these two IP addresses when transmitting data with MPQUIC.

Performance Management Function (PMF) Parameters, if Performance Measurements are enabled for the MA PDU Session. It contains:

- e. PMF Address Information: (a) the IP address for the PMF in the UPF, (b) the port number of PMF in the UPF to be used over 3GPP access, (c) the port number of PMF in the UPF to be used over non-3GPP access.

[0095] The ATSSS Control Parameters element provided by UPF-2 142 that are included in the PFCP Session Establishment Response message transmitted at step S724 includes the above elements. The UPF-1 141 receives these parameters in PFCP Session Establishment Request message transmitted at step S726 and are used by UPF-1 to establish MPTCP/MPQUIC/PMF communication with UPF-2. Specifically, the MPTCP Address information, the MPQUIC Address information and the PMF Address information help the UPF-1 141 determine how to connect with the MPTCP, MPQUIC and PMF functionality in UPF-2 142, respectively.

[0096] The ATSSS Control Parameters element provided by UPF-1 141 that are included in the PFCP Session Establishment Response message transmitted at step S728 includes the above elements. The UE 104 receives these parameters in the DL NAS Transport message transmitted at step S734 and are used by UE 104 to establish MPTCP/MPQUIC/PMF communication with UPF-1 141. Specifically, the MPTCP Address information, the MPQUIC Address information and the PMF Address information help the UE 104 determine how to connect with the MPTCP, MPQUIC and PMF functionality in UPF-1 141, respectively.

[0097] The SMF 145 creates a PDU Session Establishment Accept message for the UE 104 and encapsulates this message within an N1N2 Message Transfer Request, which is sent from the SMF 145 at step S730 to the AMF 143. The PDU Session Establishment Accept message includes an ATSSS Container element that contains the created ATSSS rules and also contains Proxy Information (UPF-1 Proxy Information) that enables the UE 104 to communicate with the proxy in UPF-1.

[0098] The AMF 143 requests from the access network (that has been selected by the UE 104 to use for requesting the MA PDU Session) to allocate the necessary resources for the

MA PDU Session by transmitting, at step S732, a NGAP PDU Session Resource Setup Request message to the access network. This message encapsulates a DL NAS Transport message to be sent to UE 104, which contains the PDU Session Establishment Accept message.

[0099] The MA PDU Session establishment procedure is completed by the UE 104 receiving the DL NAS Transport message transmitted, at step S734, from the AMF 143. This message contains the PDU Session Establishment Accept message created by the SMF 145, which includes the ATSSS rules and Proxy Information (UPF-1 Proxy Information) that enables the UE 104 to communicate with the proxy in UPF-1.

[0100] After the MA PDU Session with two PSAs is established using the process 700, the UE 104 can start sending uplink data traffic to UPF-1 141, and UPF-2 142 can start sending downlink data traffic to UPF-1 141. Such user-plane procedures are discussed in more detail below.

[0101] Figure 8 illustrates a process 800 to add a PSA to an existing MA PDU Session. In particular, when the MA PDU Session is initially established with one PSA (using known techniques), embodiments of the present disclosure extend to the SMF 145 modifying the MA PDU Session so that a second PSA is added to the data path such that the MA PDU Session has multiple PSAs (i.e. multiple UPFs).

[0102] At step S802, a known MA PDU Session establishment procedure is executed with one PSA using known techniques (see TS 23.502). In particular, a MA PDU Session is established with UPF-2 142.

[0103] At step S804, the SMF 145 determines to add a second PSA to the already established MA PDU Session. This determination may be based on the location of the UE 104. After this determination, the SMF 145 selects a UPF (UPF-1) which is going to implement the UL CL functionality and the second PSA functionality.

[0104] At step S806, the SMF 145 creates Multi-Access Rules (MAR) for UPF-1.

[0105] At step S808, the SMF 145 creates Forward Action Rules (FAR) for UPF-1.

[0106] The SMF 145 modifies the Packet Forwarding Control Protocol (PFCP) session (also known as N4 session) with UPF-2 142 by transmitting, at step S810, a PFCP Session Modification Request message to UPF-2 142. The PFCP Session Modification Request message comprises a Provide ATSSS Control Information element and, optionally, new

Multi-Access Rules for UPF-2 if they should be updated. The Provide ATSSS Control Information element indicates which ATSSS functionalities should be activated in UPF-2 and information about each one. The PFCP Session Modification message contains (e.g., within the Provide ATSSS Control Information element) a new indication that indicates to UPF-2 that the allocated ATSSS resources will be used by another proxy (in UPF-1), not by the UE 104. The message transmitted at step S810 requests information enabling UPF-1 141 to communicate with UPF- 142. This indication is need by UPF-2, for example, to allocate the appropriate IP addresses and ports so that the other proxy (in UPF-1) will be able to communicate with the proxy in UPF-2.

[0107] The UPF-2 accepts the PFCP Session Modification Request and responds by transmitting, at step S812, a PFCP Session Modification Response message to the SMF 145, which includes an ATSSS Control Parameters element. The ATSSS Control Parameters element provides information about the ATSSS functionalities allocated in UPF-2. That is, PFCP Session Modification Response message comprises information enabling the UPF-1 141 to communicate with UPF-2 142.

[0108] At step S814, the SMF 145 transmits a PFCP Session Establishment Request message to UPF-1 141, which will provide the second PSA functionality and the UL CL functionality. The PFCP Session Establishment Request message contains the created MAR for UPF-1, the created Forward Action Rules (FAR) for UPF-1, the DN Name (DNN) and the Provide ATSSS Control Information element. The Forward Action Rules (FAR) for UPF-1 indicate to UPF-1 which uplink traffic should be forwarded to its N6 interface (i.e., which traffic should not be relayed to UPF-2). The PFCP Session Establishment Request message transmitted at step S814 also contains a data element which includes the information needed by UPF-1 141 to communicate with the proxy in UPF-2 142. The data element may be created by the SMF 145 from the ATSSS Control Parameters provided by UPF-2 142 at step S812. After receiving the data element, the UPF-1 knows the IP addresses, the ports, the proxy type, and other information needed to communicate with the proxy in UPF-2 142.

[0109] The UPF-1 accepts the PFCP Session Establishment Request message transmitted at step S814 and responds by transmitting a PFCP Session Establishment Response message to the SMF 145 at step S816. The PFCP Session Establishment Response message transmitted at step S816 includes information enabling the UE 104 to communicate

with the UPF-1 141 e.g. by including its own ATSSS Control Parameters element that provides information about the ATSSS functionalities allocated in UPF-1 141.

[0110] The SMF 145 creates a PDU Session Modification Command message for the UE 104 and encapsulates this message within an N1N2 Message Transfer Request, that is sent from the SMF 145 at step S818 to the to the AMF 143. The PDU Session Modification Command message contains Proxy Information (UPF-1 Proxy Information) that enables the UE 104 to communicate with the new proxy in UPF-1 141. That is, the PDU Session Modification Command message includes the information enabling the UE 104 to communicate with the UPF-1 141 received by the SMF 145 at step S816. It may also include an ATSSS Container element that contains updated ATSSS rules if there is need to update these rules.

[0111] At step S820, the AMF 143 transmits to any of the available access networks a NGAP Downlink NAS Transport message, which encapsulates a DL NAS Transport message to be sent to the UE 104 that contains the PDU Session Modification Command.

[0112] The MA PDU Session modification procedure is completed by the UE 104 receiving, at step S822, the DL NAS Transport message from the AMF 143 via the access network. The DL NAS Transport message contains the PDU Session Modification Command created by the SMF 145, which includes Proxy Information (UPF-1 Proxy Information) that enables the UE 104 to communicate with the proxy in UPF-1 141 and, optionally, the updated ATSSS rules.

[0113] Finally, the UE 104 responds by transmitting at step S824 an UL NAS Transport message that contains a PDU Session Modification Complete message. At step S826, the access network 120,130 forwards the UL NAS Transport message to the AMF 143 within a NGAP Uplink NAS Transport message. At step S828, the AMF 143 transmits an Update SM Context Request message to the SMF 145. This message encapsulates the PDU Session Modification Complete message provided by the UE 104. That is, the PDU Session Modification Complete message is relayed to the SMF 145 by the AMF 143. The SMF 145 responds by transmitting an Update SM Context Response message to the AMF 143.

[0114] After the addition of the new PSA (UPF-1), the UE 104 should stop using communication with UPF-2 and should initiate communication with UPF-1 using the

information received at step S822 i.e. the proxy Information (UPF-1 Proxy Information) that enables the UE 104 to communicate with the proxy in UPF-1 141.

User plane procedures

[0115] The user-plane aspects of the present disclosure are now described, i.e., how data traffic flows between the UE 104, UPF-1 141 and UPF-2 142 after a MA PDU Session has been established.

[0116] Figure 9 illustrates user plane data flow with two PSAs when MPQUIC steering functionality is applied in the MA PDU Session using a *connect-ip* proxy so it can support all types of IP traffic (including IP/TCP, IP/UDP, etc.). Alternatively, the MPQUIC steering functionality can be applied in the MA PDU Session using a *connect-udp* proxy so it can support only IP/UDP traffic (not shown in Figure 9).

[0117] At step S902 a MA PDU Session with two PSAs is established. The MA PDU Session with two PSAs may be established using any of the methods described herein.

[0118] Since the MPQUIC steering functionality is applied for this MA PDU Session, at step S904 the UE 104 requests the establishment of one or more multipath QUIC connections, as specified in the present 3GPP specifications (e.g., TS 23.501). The UE 104 applies the proxy information received in the PDU Session Establishment Accept message, so the multipath QUIC connections are established between the UE 104 and UPF-1 141.

[0119] At step S906, the UPF-1 141 establishes the same number of multipath QUIC connections with UPF-2 142 by applying its own proxy information (e.g. proxy information received at step S726. There is a 1-to-1 mapping between the QUIC connections from UE 104 to UPF-1 141 and the QUIC connections from UPF-1 141 to UPF-2 142.

[0120] In each of the established multipath QUIC connections, at step S908 the UE 104 sends an HTTP CONNECT request in order to establish an IP tunnel over HTTP with the proxy in UPF-1 141. The “:protocol” pseudo-header in this request is set to “connect-ip” as defined in *draft-ietf-masque-connect-ip*. When the UPF-1 receives an HTTP CONNECT request from the UE 104 over a multipath QUIC connection, at step S910 it sends another HTTP CONNECT request to UPF-2 141 over a corresponding multipath QUIC connection, in order to establish another IP tunnel over HTTP with the proxy in UPF-2 141. If the IP tunnel is accepted by UPF-2 141, at step S912 UPF-2 141 responds with an HTTP 200

message, which triggers UPF-1 141 to accept the IP tunnel requested by the UE 104 and to respond by transmitting another HTTP 200 message, at step S914 to the UE 104.

[0121] If there are multiple multipath QUIC connections, there also multiple communication tunnels, one tunnel per connection. A "communication tunnel" can be either an IP communication tunnel that supports all types of IP traffic (UDP, TCP, etc.), or a UDP communication tunnel that supports only UDP traffic. The type of the communication tunnel (UDP or IP) depends on the type of proxy configured in UPF-1 and UPF-2 ("connect-udp" or "connect-ip" respectively). The type of proxy for the communication session is determined by SMF 145 and can be indicated to UPF-1 and UPF-2 within the "Provide ATSSS Control Information" element in PFCP Session Establishment Request messages (e.g. transmitted at steps S722 and S726).

[0122] Each of the one or more multipath QUIC connections established at step S904 supports data communication between the UE 104 and UPF-1 141 over the plurality of access paths (e.g. 3GPP access path 125 and non-3GPP access path 135). Similarly, each of the one or more multipath QUIC connections established at step S906 support data communication between UPF-1 141 and UPF-2 142 over a corresponding one of the plurality of access paths.

[0123] Data traffic received at UPF-1 141 from UE 104 via a multipath QUIC connection between the UE 104 and UPF-1 141 is forwarded to UPF-2 via the associated multipath QUIC connection in the second set. Similarly, data traffic received at UPF-1 141 from UPF-2 142 via a multipath QUIC connection UPF-1 141 and UPF-2 142 is forwarded to UE 104 via the associated multipath QUIC connection between the UE 104 and UPF-1 141.

[0124] At step S916, the UE 104 sends an IP packet (IP packet 1) to UPF-1 141 via the established IP tunnel over a multipath QUIC connection and encapsulated within a QUIC Datagram frame.

[0125] At step S918, the UPF-1 decrypts and decapsulates the IP packet and applies its Forward Action Rules (FAR) to determine how to handle this packet. In the example shown in Figure 9, the UPF-1 141 decides to forward the IP packet to its local N6 interface and at step S920 transmits the IP packet (IP packet 1) to the DN150 (e.g. to a local host device 153).

[0126] At step S922, the UE 104 sends another IP packet (IP packet 2) to UPF-1 141 via the established IP tunnel over a multipath QUIC connection and encapsulated within a QUIC Datagram frame.

[0127] At step S924, the UPF-1 141 decrypts and decapsulates the IP packet and applies again its Forward Action Rules (FAR) to determine how to handle this packet. In this case, the UPF-1 decides to forward the IP packet to the next proxy (UPF-2). Hence, it encapsulates the IP packet into another QUIC Datagram frame and at step S926 sends it to UPF-2 via the established IP tunnel over a corresponding multipath QUIC connection. Finally, the UPF-2 decrypts and decapsulates the IP packet and at step S928 forwards it to its local N6 interface.

[0128] If UPF-1 141 received the IP packet (IP packet 2) over an access path associated with 3GPP radio access 125, it forwards the IP packet (IP packet 2) to UPF-2 142 using an access path also associated with 3GPP radio access. Similarly, if UPF-1 141 received the IP packet (IP packet 2) over an access path associated with non-3GPP radio access 135, it forwards the IP packet (IP packet 2) to UPF-2 142 using an access path also associated with non-3GPP radio access. That is UPF-1 141 is configured to relay a data message to UPF-2 142 using an access path having the same access path type as the access path type used to receive the data message from the UE 104.

[0129] Figure 9 illustrates how UPF-1 handles uplink traffic, but for completeness we also describe herein how UPF-1 handles downlink traffic. When an IP packet arrives at UPF-1 141 via its N6 interface (not shown in Figure 9), the UPF-1 141 applies its Multi-Access Rules (MAR) to determine the access path (i.e., the N3 interface) over which it should be forwarded to UE 104. Based on these rules, the UPF-1 141 determines to forward the IP packet to the UE 104 either via an N3 interface associated with 3GPP access, or via an N3 interface associated with non-3GPP access.

[0130] Similarly, when an IP packet arrives at UPF-2 via its N6 interface (not shown in Figure 9), the UPF-2 applies its Multi-Access Rules (MAR) to determine the access path (i.e., the N9 interface) over which it should be forwarded to UPF-1 141. When the UPF-1 receives the IP packet, it forwards it to the UE 104 via a corresponding access path. For example, if UPF-1 receives the IP packet over an N9 interface associated with 3GPP access, it forwards it to UE 104 via an N3 interface associated also with 3GPP access.

[0131] Figure 10 illustrates the protocol layers involved in the user-plane communication via a MA PDU Session with two PSAs in the example where the MPQUIC steering functionality is applied. Figure 10 shows the one or more multipath QUIC connections 1002

established at step S904 between the UE 104 and UPF-1 141, and the one or more multipath QUIC connections 1004 established at step S906 between the UPF-1 141 to UPF-2 142

[0132] In the example shown in Figure 10, the UE 104 transmits two different IP flows (a first IP flow 1006 and a second IP flow 1008), each one composed of IP packets with the same 5-tuple.

[0133] The first IP flow 1006 and the second IP flow 1008 may comprise IP packets comprising data of different data formats. For example the first IP flow 1006 may comprise IP packets comprising audio data, whereas the second IP flow 1008 may comprise IP packets comprising video data.

[0134] Alternatively or additionally, the first IP flow 1006 and the second IP flow 1008 may be destined for different destinations. For example the first IP flow 1006 may be destined to a remote host device 155 in the DN 150 and the second IP flow 1008 may be destined to a local host device 153 in the DN 150.

[0135] As shown in Figure 10, the UPF-1 141 implements a first proxy function 1003 and the UPF-2 142 implements a second proxy function 1005. In the example shown in Figure 10, the first proxy function 1003 is a *connect-ip* type of proxy and the second proxy function 1005 is also a *connect-ip* type of proxy.

[0136] The packets of each IP flow may be split across the two access paths, as shown in Figure 10. In particular some of the packets of first IP flow 1006 and some of the packets of the second IP flow 1008 may be transmitted over the non-3GPP access path (via the non-3GPP access network 130), and some of the packets of first IP flow 1006 and some of the packets of the second IP flow 1008 may be transmitted over the 3GPP access path (via the 3GPP access network).

[0137] The QUIC layer in UPF-1 receives each of these IP packets (within a QUIC Datagram frame), and forwards them to the first proxy function 1003 (HTTP/3 proxy), which terminates the IP tunnel with the UE 104. The UL CL layer 1006 in UPF-1 141 applies the Forward Action Rules (FAR) received from SMF 145 and determines how to forward each IP packet.

[0138] If an IP packet should be forwarded by UPF-1 141 to UPF-2 142, it enters again the QUIC layer where it is encapsulated into another QUIC Datagram frame and is sent to UPF-2 142 via a multipath QUIC connection 1004. If an IP packet should be forwarded by

UPF-1 141 to DN 150 via the local N6 interface, it enters the protocol stack of the N6 interface. Similar operation applies for the IP flows in the downlink direction (IP flows received in the UE).

[0139] Figure 11 illustrates user plane data flow with two PSAs when MPTCP steering functionality is applied in the MA PDU Session either in addition to, or instead of, the MPQUIC steering functionality described above.

[0140] At step S1101 a MA PDU Session with two PSAs is established. The MA PDU Session with two PSAs may be established using any of the methods described herein.

[0141] Taking an example, whereby the UE 104 wants to establish a TCP connection with a device (e.g. Host 1) in the DN 150. Since the UE 104 is configured to use an MPTCP proxy in UPF-1 141, at step S1102 the UE 104 sends a message to UPF-1 requesting a TCP connection to Host 1 in the DN 150. In particular, at step S1102 the UE 104 transmits an IP packet to UPF-1 141 containing a TCP message with the SYN flag set, with a MPTCP option, and with identifiers of Host 1 in the data element. The identifiers associated with the device (Host 1) may be the IP address of the device and a target TCP port in the device. Instead of an IP address of the device (e.g. "192.2.3.4"), the TCP message may contain a domain name for the device (e.g. "www.example.com").

[0142] Based on the Forward Action Rules (FAR), at step S1104 the UPF-1 141 decides to establish the requested TCP connection with Host 1 directly via its N6 interface. For this purpose, at step S1106 the UPF-1 sends to Host 1 another IP packet containing a TCP message with the SYN flag set and with the MPTCP option. The Host 1 accepts the TCP connection request and responds at step S1108 with another IP packet containing a TCP message with the SYN and ACK flags set. At step S1110, the UPF-1 141 transmits an IP packet containing a TCP message with the SYN and ACK flags set and with the MPTCP option. At step S1112, UE 104 transmits an IP packet containing a TCP message with the ACK flag set to the UPF-1 141, which is relayed by the UPF-1 141 at step S1114 to Host 1 in the DN 150.

[0143] Finally, at step S1116 a first MPTCP connection is established between the UE 104 and UPF-1 141, and at step S1118 a second TCP connection is established between UPF-1 141 and Host 1. These two TCP connections are bound together in UPF-1, which relays TCP messages between these connections. The second TCP connection established between

UPF-1 141 and Host 1 may or may not to be a MPTCP connection depending on the capabilities of Host 1.

[0144] Taking an example, whereby the UE 104 wants to establish a TCP connection with a device (e.g. Host 2) in the DN 150. Since the UE 104 is configured to use an MPTCP proxy in UPF-1, at step S1120 the UE 104 sends a message to UPF-1 requesting a TCP connection to Host 2 in the DN 150. In particular, at step S1120 the UE 104 transmits an IP packet containing a TCP message with the SYN flag set, with the MPTCP option, and with the identifiers of Host 2 in the data element. The identifiers associated with the device (Host 2) may be the IP address of the device and a target TCP port in the device. Instead of an IP address of the device (e.g. "192.2.3.4"), the TCP message may contain a domain name for the device (e.g. "www.example.com").

[0145] Based on the Forward Action Rules (FAR), at step S1122 the UPF-1 decides to establish the requested TCP connection with Host 2 via the proxy in UPF-2 142. For this purpose, at step S1124 the UPF-1 141 sends to UPF-2 142 another IP packet containing a TCP message with the SYN flag set, with the MPTCP option, and with the address and port of Host 2 in the data element. In turn, at step S1126 UPF-2 sends to Host 2 another IP packet containing a TCP message with the SYN flag set and with the MPTCP option. The Host 2 accepts the TCP connection request and responds at step S1128 with another IP packet containing a TCP message with the SYN and ACK flags set.

[0146] At step S1130, the UPF-2 142 transmits an IP packet containing a TCP message with the SYN and ACK flags set and with the MPTCP option to UPF-1 141 which is then relayed to the UE 104 at step S1132.

[0147] Normal TCP message exchange continues such that at step S1134 the UE 104 transmits an IP packet containing a TCP message with the SYN and ACK flags set and with the MPTCP option to UPF-1 141, which is then relayed at step S1136 to UPF-2 142 and to Host 2 at step S1138.

[0148] Finally, a first MPTCP connection is established between the UE 104 and UPF-1 141, a second MPTCP connection is established between UPF-1 141 and UPF-2 142, and a third TCP connection is established between UPF-2 142 and Host 2 in the DN 150. The first and the second MPTCP connections are bound together in UPF-1, while the second and the third TCP connections are bound together in UPF-2. The first MPTCP connection and the

second MPTCP connection are associated in that whatever data is received at the UPF-1 141 on one of them is forwarded on to the other.

[0149] Figure 12 illustrates an example of a processor 1200 in accordance with aspects of the present disclosure. The processor 1200 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 1200 may include a controller 1202 configured to perform various operations in accordance with examples as described herein. The processor 1200 may optionally include at least one memory 1204, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 1200 may optionally include one or more arithmetic-logic units (ALUs) 1206. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0150] The processor 1200 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 1200) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0151] The controller 1202 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 1200 to cause the processor 1200 to support various operations in accordance with examples as described herein. For example, the controller 1202 may operate as a control unit of the processor 1200, generating control signals that manage the operation of various components of the processor 1200. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0152] The controller 1202 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 1204 and determine subsequent instruction(s) to be executed to cause the processor 1200 to support various operations in accordance with examples as described herein. The controller 1202 may be configured to track memory address of instructions associated with the memory 1204. The controller 1202 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 1202 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 1200 to cause the processor 1200 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 1202 may be configured to manage flow of data within the processor 1200. The controller 1202 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 1200.

[0153] The memory 1204 may include one or more caches (e.g., memory local to or included in the processor 1200 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 1204 may reside within or on a processor chipset (e.g., local to the processor 1200). In some other implementations, the memory 1204 may reside external to the processor chipset (e.g., remote to the processor 1200).

[0154] The memory 1204 may store computer-readable, computer-executable code including instructions that, when executed by the processor 1200, cause the processor 1200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 1202 and/or the processor 1200 may be configured to execute computer-readable instructions stored in the memory 1204 to cause the processor 1200 to perform various functions. For example, the processor 1200 and/or the controller 1202 may be coupled with or to the memory 1204, the processor 1200, the controller 1202, and the memory 1204 may be configured to perform various functions described herein. In some examples, the processor 1200 may include multiple processors and the memory 1204 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple

memories, which may, individually or collectively, be configured to perform various functions herein.

[0155] The one or more ALUs 1206 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 1206 may reside within or on a processor chipset (e.g., the processor 1200). In some other implementations, the one or more ALUs 1206 may reside external to the processor chipset (e.g., the processor 1200). One or more ALUs 1206 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 1206 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 1206 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 1206 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 1206 to handle conditional operations, comparisons, and bitwise operations.

[0156] The processor 1200 may support wireless communication in accordance with examples as disclosed herein. The processor 1200 may be configured to or operable to support a means for performing the methods described herein.

[0157] Figure 13 illustrates an example of a NE 1300 in accordance with aspects of the present disclosure. The NE 1300 may include a processor 1302, a memory 1304, a controller 1306, and a transceiver 1308. The processor 1302, the memory 1304, the controller 1306, or the transceiver 1308, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces. The NE 1300 may correspond to the SMF 145. Alternatively or additionally, the NE 1300 may correspond to UPF-1 141 and/or UPF-2 142.

[0158] The processor 1302, the memory 1304, the controller 1306, or the transceiver 1308, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any

combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0159] The processor 1302 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 1302 may be configured to operate the memory 1304. In some other implementations, the memory 1304 may be integrated into the processor 1302. The processor 1302 may be configured to execute computer-readable instructions stored in the memory 1304 to cause the NE 1300 to perform various functions of the present disclosure.

[0160] The memory 1304 may include volatile or non-volatile memory. The memory 1304 may store computer-readable, computer-executable code including instructions when executed by the processor 1302 cause the NE 1300 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 1304 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0161] In some implementations, the processor 1302 and the memory 1304 coupled with the processor 1302 may be configured to cause the NE 1300 to perform one or more of the functions described herein (e.g., executing, by the processor 1302, instructions stored in the memory 1304). For example, the processor 1302 may support wireless communication at the NE 1300 in accordance with examples as disclosed herein.

[0162] In embodiments whereby the NE 1300 corresponds to the SMF 145, the NE 1300 may be configured to support a means for receiving a request message to establish a multi-access communication session for a user equipment (UE) and a data network; selecting a first user plane function (UPF) and a second UPF for the multi-access communication session, wherein the first UPF and second UPF are configured to route data associated with the multi-access communication session and the data network; transmitting first multi-access rules and forward-action rules to the first UPF; transmitting second multi-access rules to the second UPF; and transmitting a response that indicates an acceptance to establish the multi-access

communication session, wherein the response comprises information that enables the UE to communicate with the first UPF.

[0163] In embodiments whereby the NE 1300 corresponds to the SMF 145, the NE 1300 may be configured to support a means for determining to add a first user plane function (UPF) to a multi-access communication session established for a user equipment (UE), a second UPF and a data network, wherein the first UPF and the second UPF are configured to route data associated with the multi-access communication session and the data network; transmitting first multi-access rules and forward-action rules to the first UPF; and transmitting a message that comprises information that enables the UE to communicate with the first UPF.

[0164] In embodiments whereby the NE 1300 corresponds to the UPF-1 141, the NE 1300 may be configured to support a means for establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receiving a data message via a first access path for transmission to the data network; determining whether to transmit the data message directly to the data network or to the data network via the further user plane function network entity; and in response to a determination to transmit the data message to the data network via the further user plane function network entity, transmitting the data message to the further user plane function network entity via a second access path having the same access path type as the first access path.

[0165] In embodiments whereby the NE 1300 corresponds to the UPF-1 141, the NE 1300 may be configured to support a means for establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receiving a TCP message from the UE requesting a TCP connection to a device in the data network; determining to establish the TCP connection directly with the device in the data network; and in response to said determination, establishing a first TCP connection with the UE and establishing a second TCP connection with the device, wherein the first TCP connection supports multipath communication over the plurality of access paths.

[0166] In embodiments whereby the NE 1300 corresponds to the UPF-1 141, the NE 1300 may be configured to support a means for establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths; receiving a message from the UE requesting a TCP connection to a device in the data network; determining to establish the TCP connection to the device in the data network via the further user plane function network entity; and in response to said determination, establishing a first multipath TCP connection with the user equipment and an associated second multipath TCP connection with the further user plane function network entity, wherein the first and the second multipath TCP connections support multipath communication over the plurality of access paths.

[0167] The controller 1306 may manage input and output signals for the NE 1300. The controller 1306 may also manage peripherals not integrated into the NE 1300. In some implementations, the controller 1306 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 1306 may be implemented as part of the processor 1302.

[0168] In some implementations, the NE 1300 may include at least one transceiver 1308. In some other implementations, the NE 1300 may have more than one transceiver 1308. The transceiver 1308 may represent a wireless transceiver. The transceiver 1308 may include one or more receiver chains 1310, one or more transmitter chains 1312, or a combination thereof.

[0169] A receiver chain 1310 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 1310 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 1310 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 1310 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 1310 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0170] A transmitter chain 1312 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 1312 may include at least one

modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 1312 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 1312 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0171] Figure 14 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method of Figure 14 may be implemented by a NE as described herein (e.g. a SMF 145). In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0172] At 1402, the method may include receiving a request message to establish a multi-access communication session for a user equipment (UE) and a data network. The operations of 1402 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1402 may be performed by a NE as described with reference to Figure 13.

[0173] At 1404, the method may include selecting a first user plane function (UPF) and a second UPF for the multi-access communication session, wherein the first UPF and the second UPF are configured to route data associated with the multi-access communication session and the data network. The operations of 1404 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1404 may be performed by a NE as described with reference to Figure 13.

[0174] At 1406, the method may include transmitting first multi-access rules and forward-action rules to the first UPF. The operations of 1406 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1406 may be performed by a NE as described with reference to Figure 13.

[0175] At 1408, the method may include transmitting second multi-access rules to the second UPF. The operations of 1408 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1408 may be performed by a NE as described with reference to Figure 13.

[0176] At 1410, the method may include transmitting a response message that indicates an acceptance to establish the multi-access communication session, wherein the response message comprises information that enables the UE to communicate with the first UPF. The operations of 1410 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1410 may be performed by a NE as described with reference to Figure 13.

[0177] Figure 15 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method of Figure 15 may be implemented by a NE as described herein (e.g. a SMF 145). In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0178] At 1502, the method may include determining to add a first user plane function (UPF) to a multi-access communication session established for a user equipment (UE), a second UPF and a data network, wherein the first UPF and the second UPF are configured to route data associated with the multi-access communication session and the data network. The operations of 1502 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1502 may be performed by a NE as described with reference to Figure 13.

[0179] At 1504, the method may include transmitting first multi-access rules and forward-action rules to the first UPF. The operations of 1504 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1504 may be performed by a NE as described with reference to Figure 13.

[0180] At 1506, the method may include transmitting a message that comprises information that enables the UE to communicate with the first UPF. The operations of 1506 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1506 may be performed by a NE as described with reference to Figure 13.

[0181] Figure 16 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method of Figure 16 may be implemented by a NE as described herein (e.g. UPF-1 141). In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0182] At 1602, the method may include establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths. The operations of 1602 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1602 may be performed by a NE as described with reference to Figure 13.

[0183] At 1604, the method may include receiving a data message via a first access path for transmission to the data network. The operations of 1604 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1604 may be performed by a NE as described with reference to Figure 13.

[0184] At 1606, the method may include determining whether to transmit the data message directly to the data network or to the data network via the further user plane function network entity. The operations of 1606 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1606 may be performed by a NE as described with reference to Figure 13.

[0185] At 1608, the method may include in response to a determination to transmit the data message to the data network via the further user plane function network entity, transmitting the data message to the further user plane function network entity via a second access path having the same access path type as the first access path. The operations of 1608 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1608 may be performed by a NE as described with reference to Figure 13.

[0186] Figure 17 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method of Figure 17 may be implemented by a NE as described herein (e.g. UPF-1 141). In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0187] At 1702, the method may include establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths. The operations of 1702 may be performed in

accordance with examples as described herein. In some implementations, aspects of the operations of 1702 may be performed by a NE as described with reference to Figure 13.

[0188] At 1704, the method may include receiving a TCP message from the UE requesting a TCP connection to a device in the data network. The operations of 1704 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1704 may be performed by a NE as described with reference to Figure 13.

[0189] At 1706, the method may include determining to establish the TCP connection directly with the device in the data network. The operations of 1706 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1706 may be performed by a NE as described with reference to Figure 13.

[0190] At 1708, the method may include in response to said determination, establishing a first TCP connection with the UE and establish a second TCP connection with the device, wherein the first TCP connection supports multipath communication over the plurality of access paths. The operations of 1708 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1708 may be performed by a NE as described with reference to Figure 13.

[0191] Figure 18 illustrates a flowchart of a method in accordance with aspects of the present disclosure. The operations of the method of Figure 18 may be implemented by a NE as described herein (e.g. UPF-1 141). In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0192] At 1802, the method may include establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths. The operations of 1802 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1802 may be performed by a NE as described with reference to Figure 13.

[0193] At 1804, the method may include receiving a message from the UE requesting a TCP connection to a device in the data network. The operations of 1804 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1804 may be performed by a NE as described with reference to Figure 13.

[0194] At 1806, the method may include determining to establish the TCP connection to the device in the data network via the further user plane function network entity. The operations of 1806 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1806 may be performed by a NE as described with reference to Figure 13.

[0195] At 1808, the method may include in response to said determination, establishing a first multipath TCP connection with the user equipment and an associated second multipath TCP connection with the further user plane function network entity, wherein the first and the second multipath TCP connections support multipath communication over the plurality of access paths. The operations of 1808 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1808 may be performed by a NE as described with reference to Figure 13.

[0196] It should be noted that the methods described herein are possible implementations, and that the operations and the steps of any of the methods described herein may be rearranged or otherwise modified and that other implementations are possible.

[0197] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

1. A user plane function network entity for wireless communication, comprising:
 - at least one memory; and
 - at least one processor coupled with the at least one memory and configured to cause the user plane function network entity to:
 - establish a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths;
 - receive a data message via a first access path for transmission to the data network;
 - determine whether to transmit the data message directly to the data network or to the data network via the further user plane function network entity; and
 - in response to a determination to transmit the data message to the data network via the further user plane function network entity, transmit the data message to the further user plane function network entity via a second access path having the same access path type as the first access path.
2. A user plane function network entity of claim 1, wherein the at least one processor is configured to cause the user plane function network entity to use forward-action rules to perform the determination.
3. A user plane function network entity of claim 1 or 2, wherein the at least one processor is configured to cause the user plane function network entity to establish a second set of one or more multipath QUIC connections with the further user plane function network entity in response to establishing a first set of one or more multipath QUIC connections with the UE, wherein each multipath QUIC connection in the second set is associated with a respective multipath QUIC connection in the first set.

4. A user plane function network entity of claim 3, wherein the at least one processor is configured to cause the user plane function network entity to:

establish a first set of one or more communication tunnels with the UE, each communication tunnel in the first set using a multipath QUIC connection in the first set of one or more multipath QUIC connections, and

establish a second set of one or more communication tunnels with the further user plane function network entity, each communication tunnel in the second set using a multipath QUIC connection in the second set of one or more multipath QUIC connections, wherein each communication tunnel in the second set is associated with a communication tunnel in the first set.

5. A user plane function network entity of claim 3, wherein the at least one processor is configured to cause the user plane function network entity to:

receive the data message via a first communication tunnel in the first set of one or more communication tunnels; and

transmit the data message to the further user plane function network entity via a second communication tunnel in the second set of one or more communication tunnels that is associated with the first communication tunnel.

6. A user plane function network entity of claim 4 or 5, wherein the at least one processor is configured to cause the user plane function network entity to:

receive downlink data from the further user plane function network entity via a second communication tunnel in the second set of one or more communication tunnels; and

transmit the downlink data to the UE via a first communication tunnel in the first set of one or more communication tunnels that is associated with the second communication tunnel.

7. A user plane function network entity of any of claims 4 to 6, wherein the at least one processor is configured to cause the network entity to select an access path of the plurality of access paths, for routing downlink data received from the further user plane function network entity to the UE, using multi-access rules.

8. A user plane function network entity of any preceding claim, wherein the at least one processor is configured to cause the user plane function network entity to:

in response to a determination to transmit the data message directly to the data network, transmit the data message to the data network.

9. A method performed by a user plane function network entity, the method comprising: establishing a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths;

receiving a data message via a first access path for transmission to the data network;

determining whether to transmit the data message directly to the data network or to the data network via the further user plane function network entity; and

in response to determining to transmit the data message to the data network via the further user plane function network entity, transmitting the data message to the further user plane function network entity via a second access path having the same access path type as the first access path.

10. A method of claim 9, the method further comprising using forward-action rules to perform the determining.

11. A method of claim 9 or 10, the method further comprising:

establishing a second set of one or more multipath QUIC connections with the further user plane function network entity in response to establishing a first set of one or more multipath QUIC connections with the UE, wherein each multipath QUIC connection in the second set is associated with a respective multipath QUIC connection in the first set.

12. A method of claim 11, the method further comprising:

establishing a first set of one or more communication tunnels with the UE, each communication tunnel in the first set using a multipath QUIC connection in the first set of one or more multipath QUIC connections, and

receiving the data message via a first communication tunnel in the first set of communication tunnels.

13. A method of claim 11 or 12, the method further comprising:

establishing a second set of one or more communication tunnels with the further user plane function network entity, each communication tunnel in the second set using a multipath QUIC connection in the second set of one or more multipath QUIC connections, wherein each communication tunnel in the second set is associated with a communication tunnel in the first set, and

transmitting the data message to the further user plane function network entity via a second communication tunnel associated with the first communication tunnel.

14. A method of any of claims 9 to 13, the method further comprising:

in response to determining to transmit the data message directly to the data network, transmitting the data message to the data network.

15. A user plane function network entity for wireless communication, comprising:

at least one memory; and

at least one processor coupled with the at least one memory and configured to cause the user plane function network entity to:

establish a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths;

receive a TCP message from the UE requesting a TCP connection to a device in the data network;

determine to establish the TCP connection directly with the device in the data network; and

in response to said determination, establish a first TCP connection with the UE and establish a second TCP connection with the device, wherein the first TCP connection supports multipath communication over the plurality of access paths.

16. A user plane function network entity of claim 15, wherein the at least one processor is configured to cause the user plane function network entity to use forward-action rules to perform the determination.

17. A user plane function network entity of claim 15 or 16, wherein the TCP message comprises an identifier indicating that the UE supports multipath TCP, and identifiers associated with the device.

18. A user plane function network entity for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the user plane function network entity to:
establish a multi-access communication session with a user equipment (UE) and a further user plane function network entity, the multi-access communication session supporting data transmission between the UE and a data network over a plurality of access paths;
receive a message from the UE requesting a TCP connection to a device in the data network;
determine to establish the TCP connection to the device in the data network via the further user plane function network entity; and
in response to said determination, establish a first multipath TCP connection with the user equipment and an associated second multipath TCP connection with the further user plane function network entity, wherein the first and the second multipath TCP connections support multipath communication over the plurality of access paths.

19. A user plane function network entity of claim 18, wherein the at least one processor is configured to cause the user plane function network entity to use forward-action rules to perform the determination.

20. A user plane function network entity of claim 18 or 19, wherein the TCP message comprises an identifier indicating that the UE supports multipath TCP, and identifiers associated with the device.

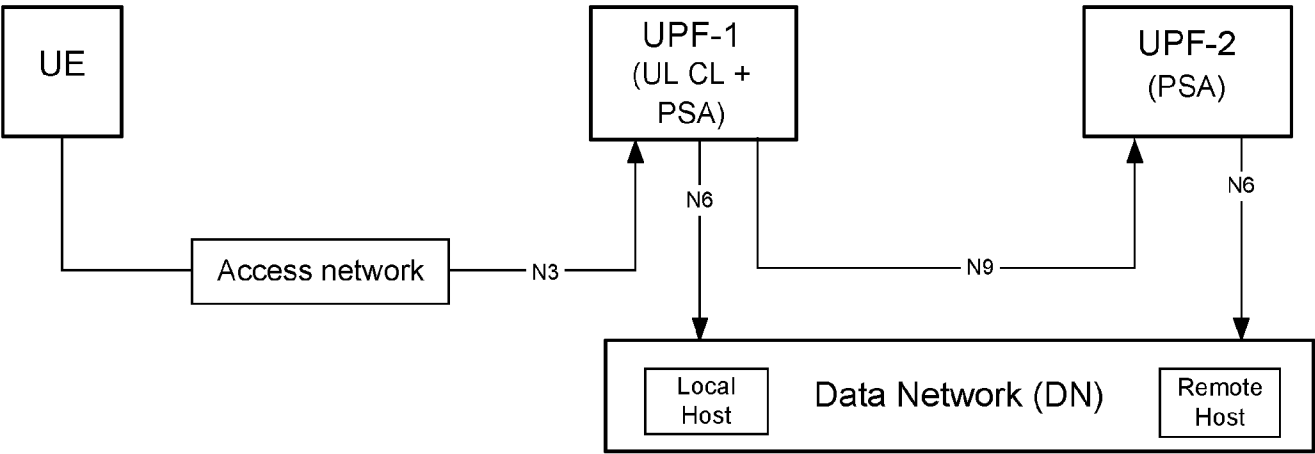


Figure 1

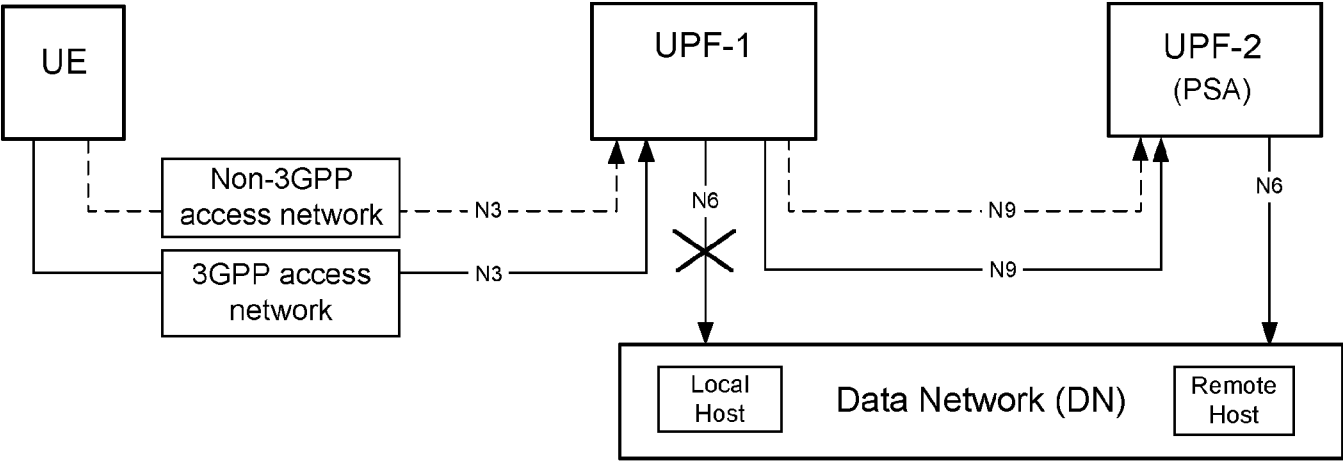


Figure 2

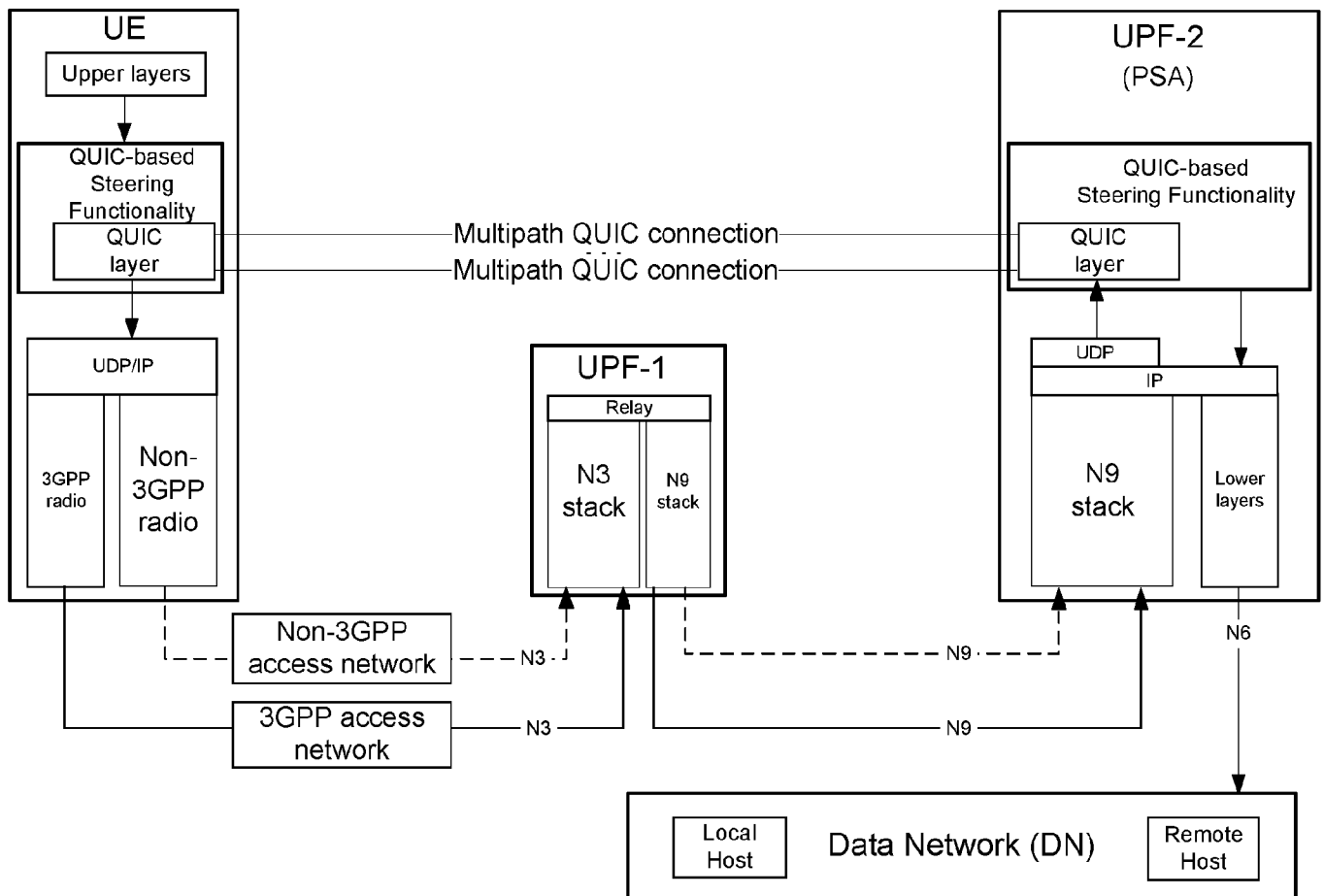


Figure 3

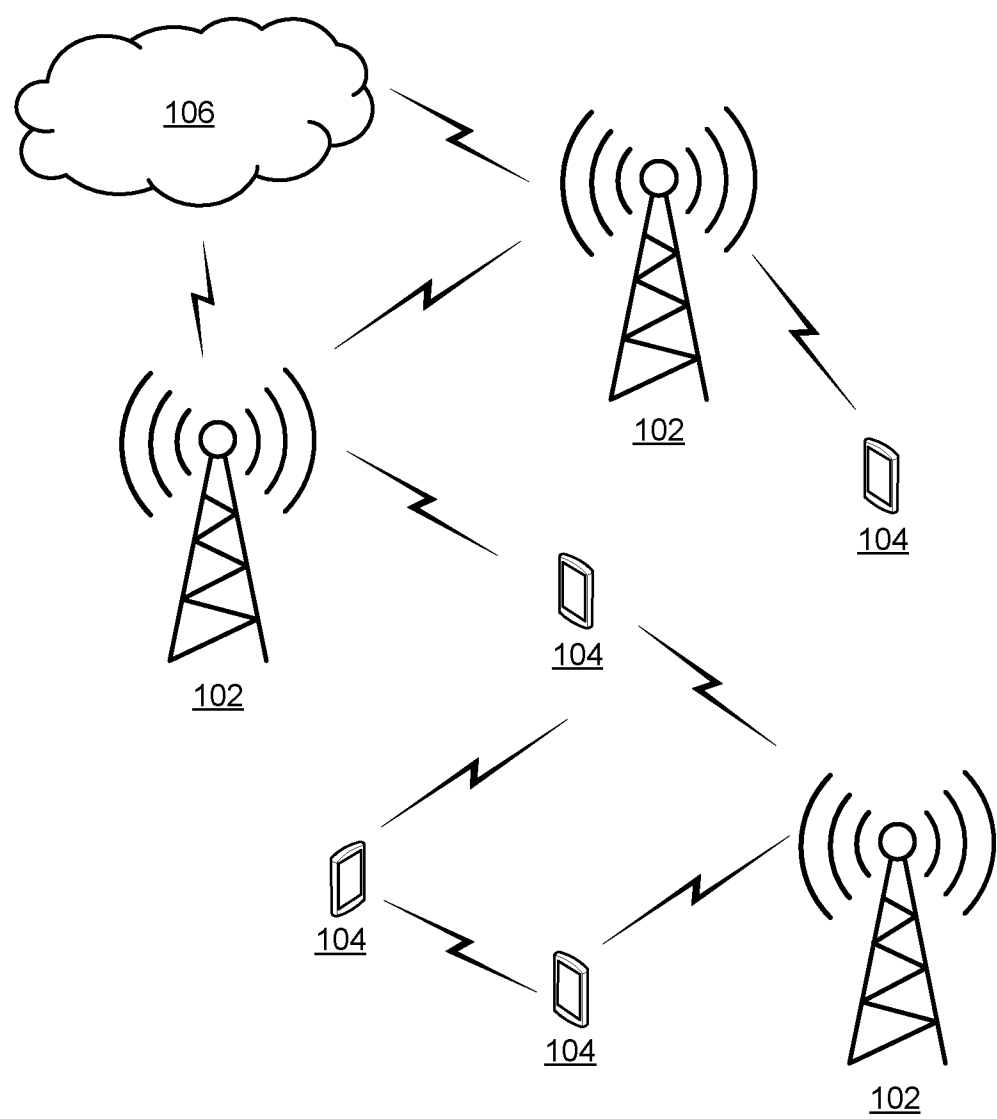


Figure 4

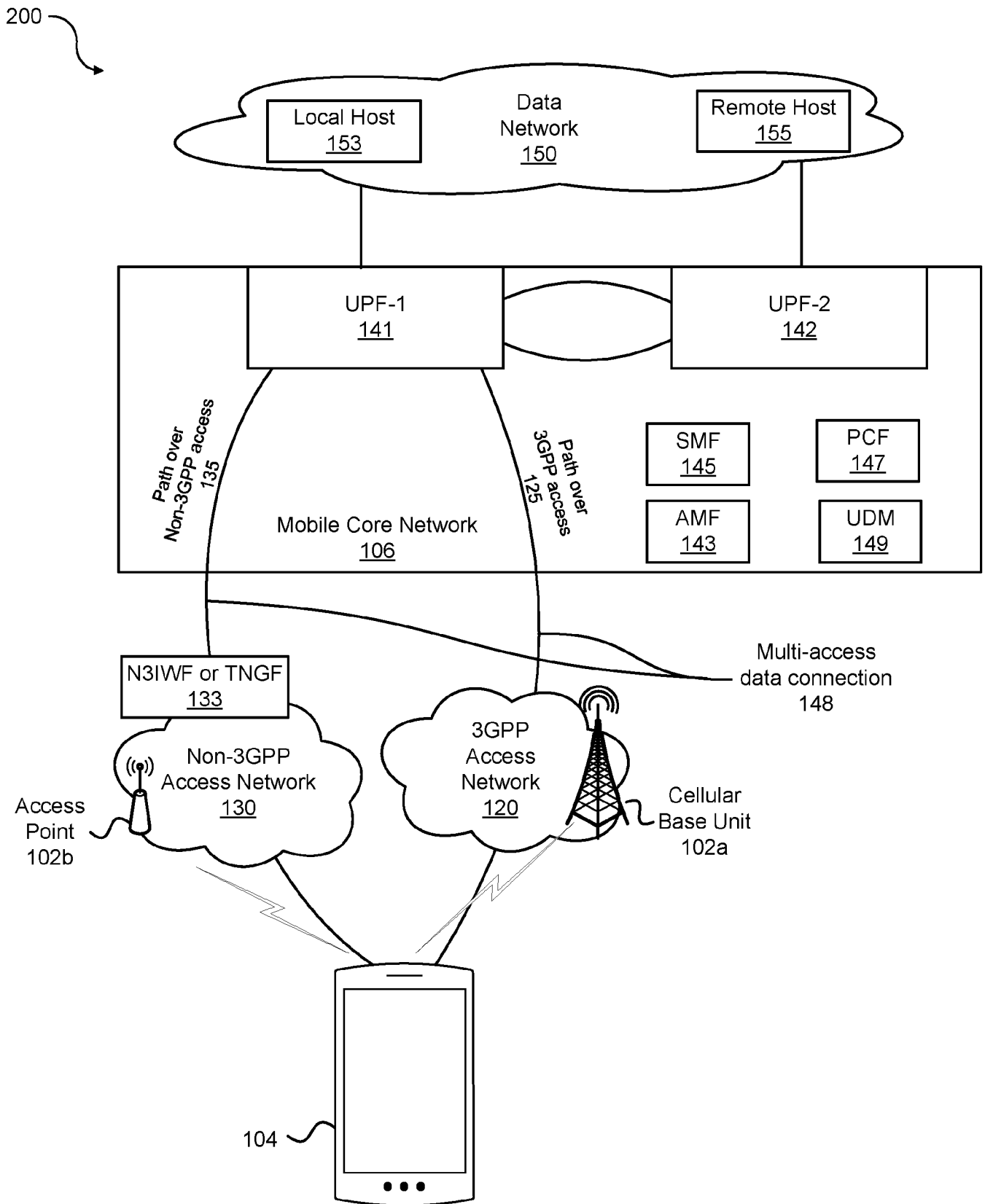


Figure 5

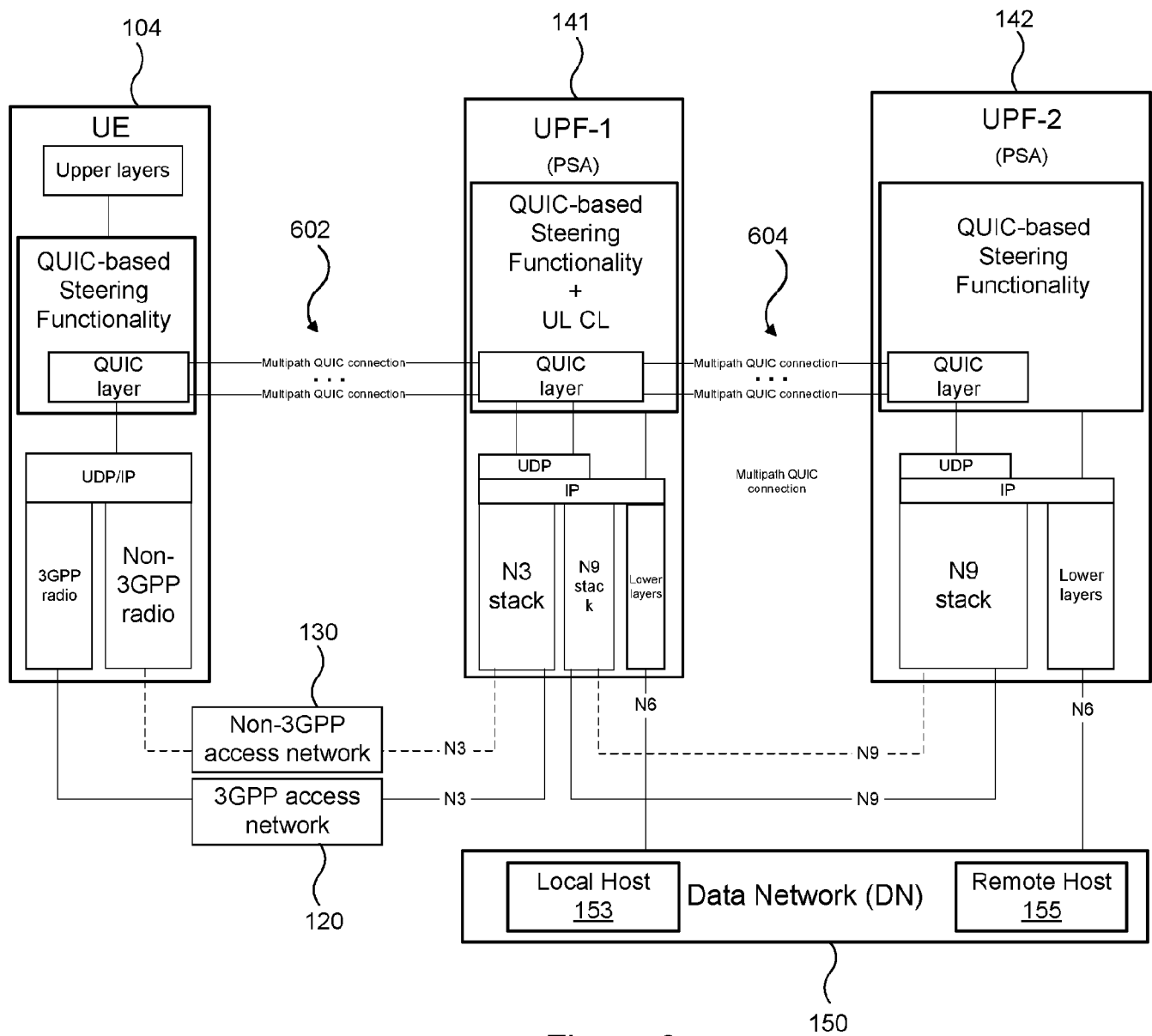


Figure 6

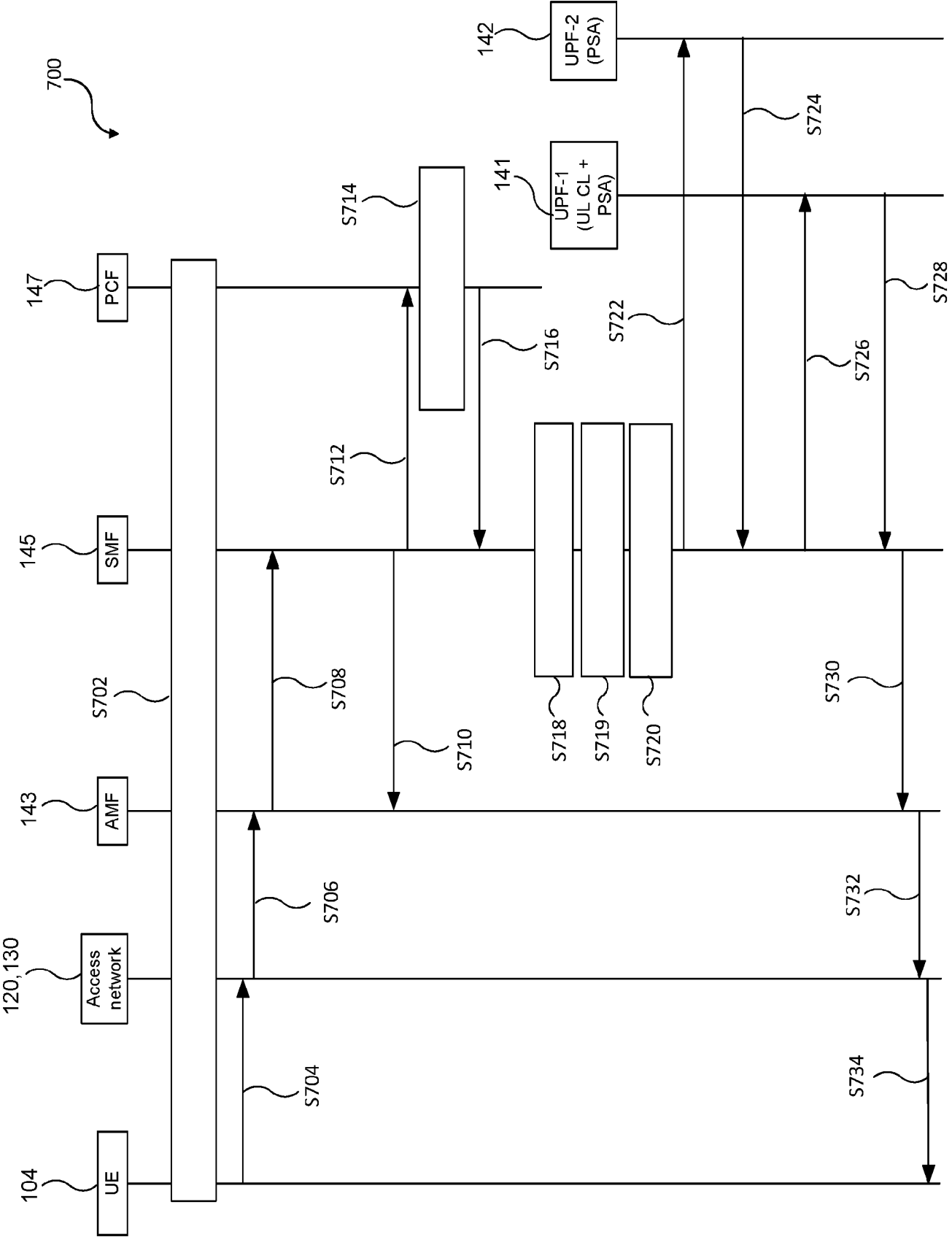


Figure 7

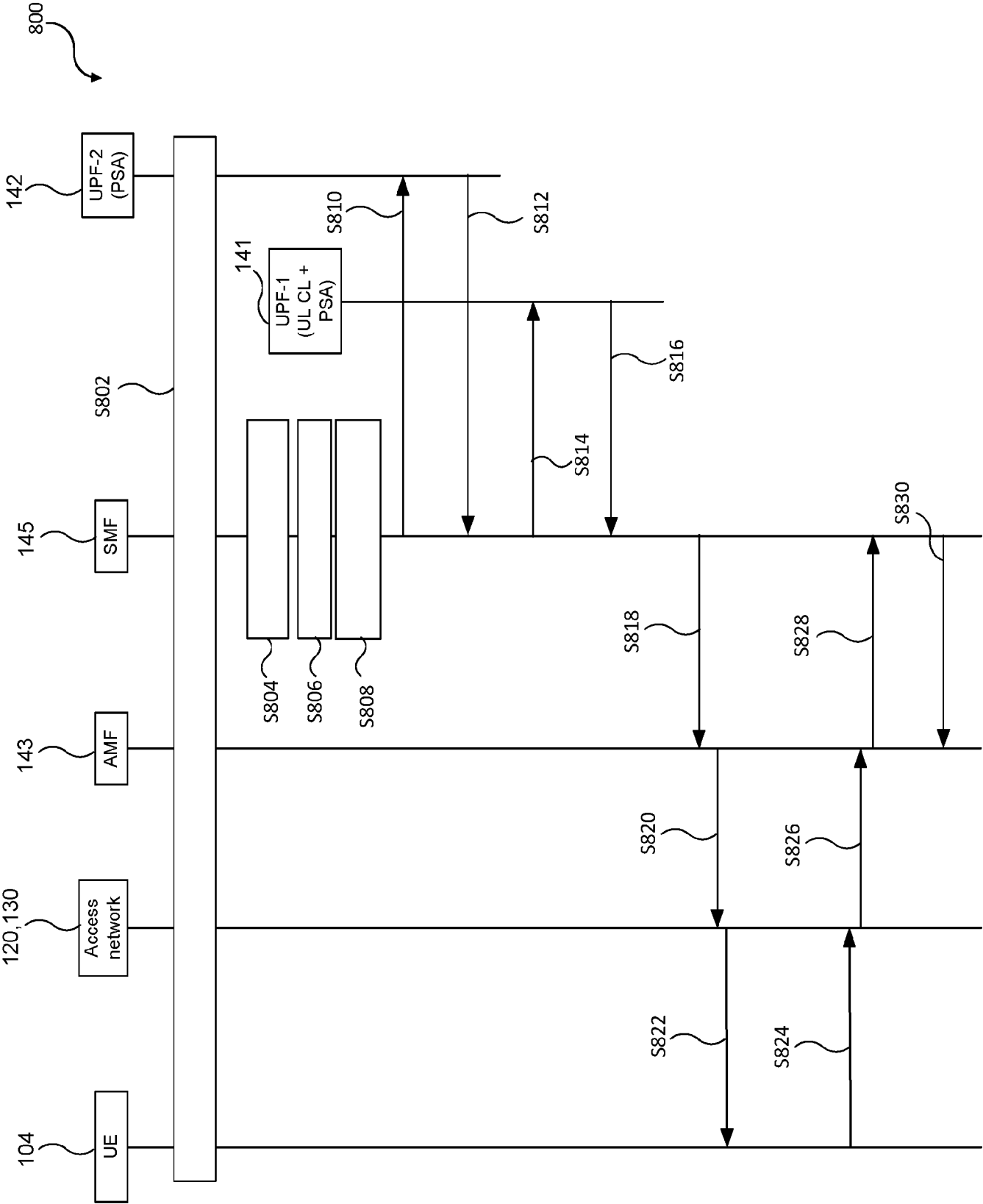


Figure 8

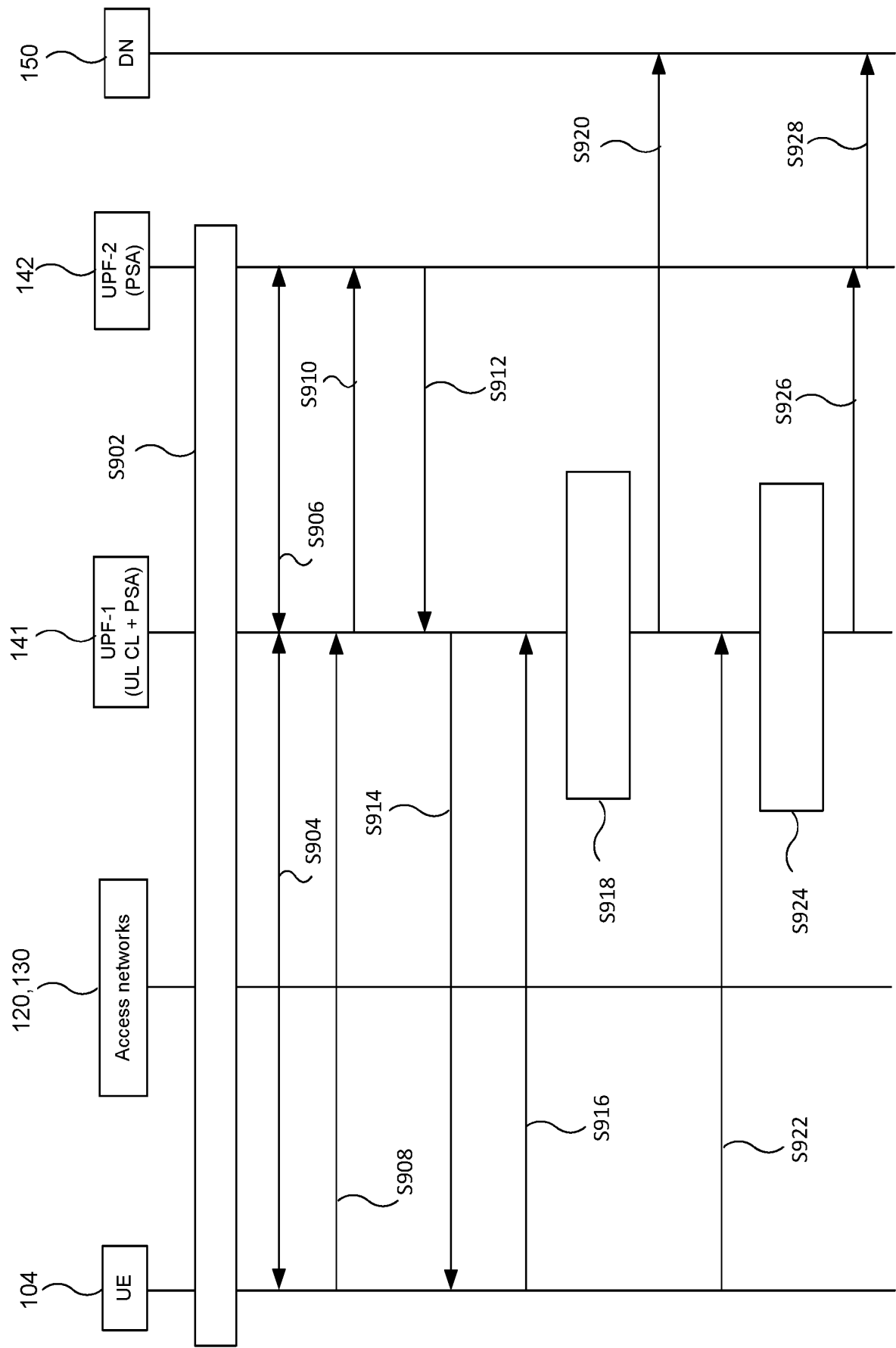


Figure 9

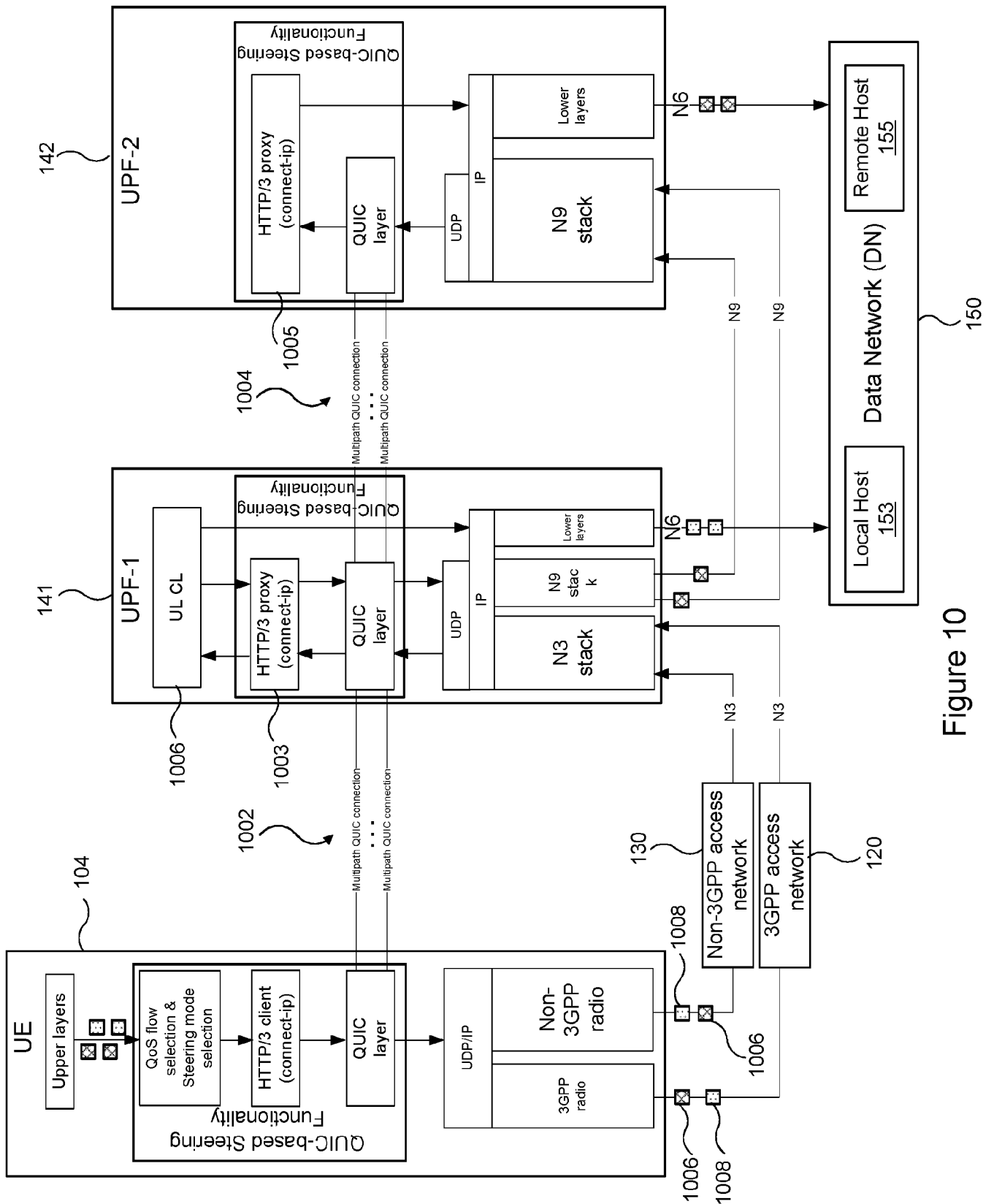


Figure 10

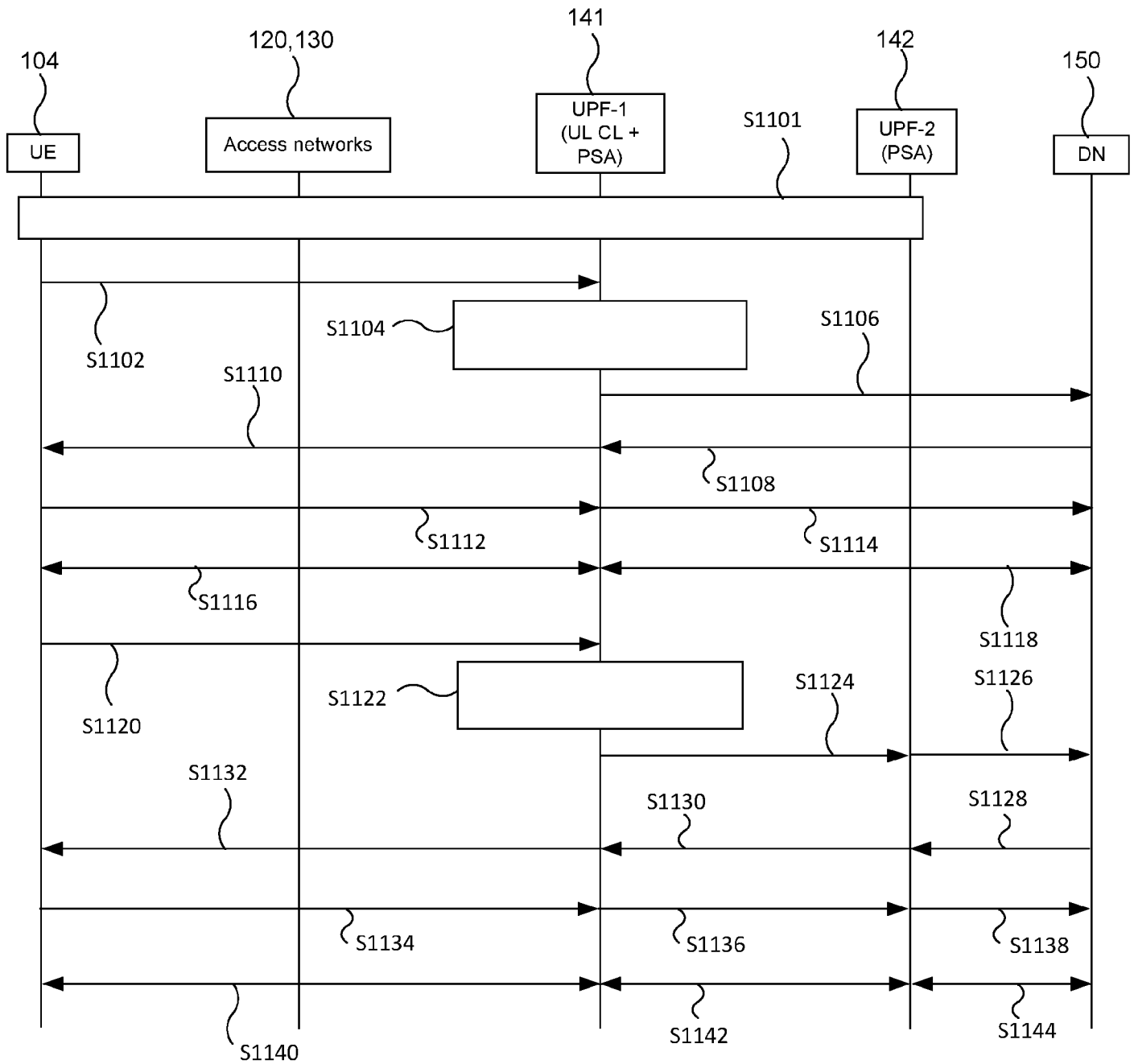


Figure 11

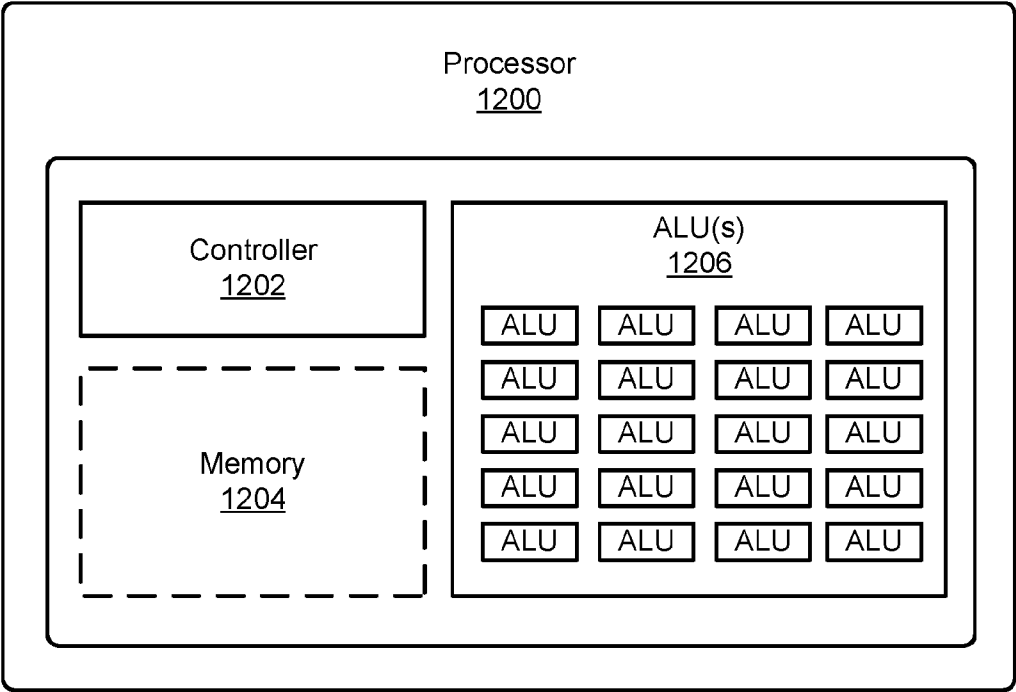


Figure 12

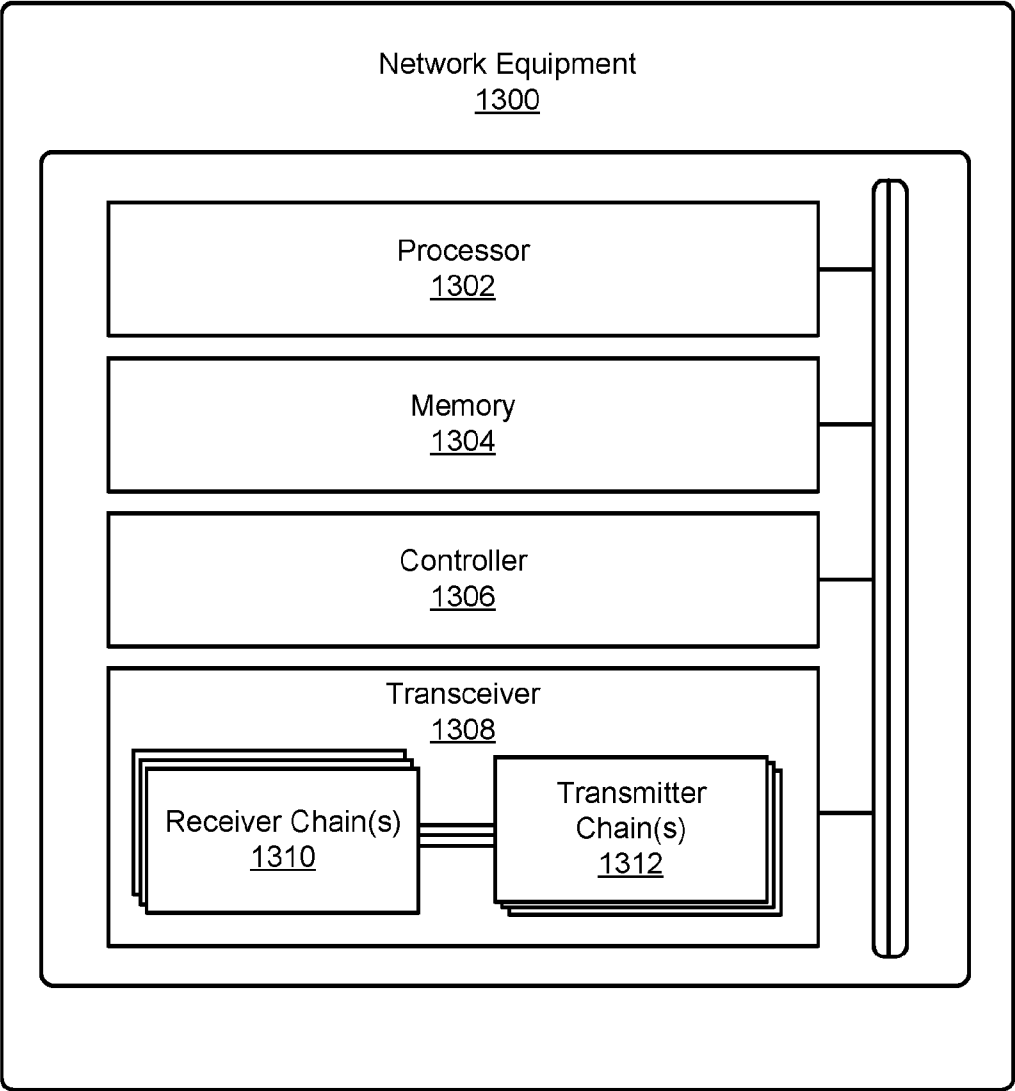


Figure 13

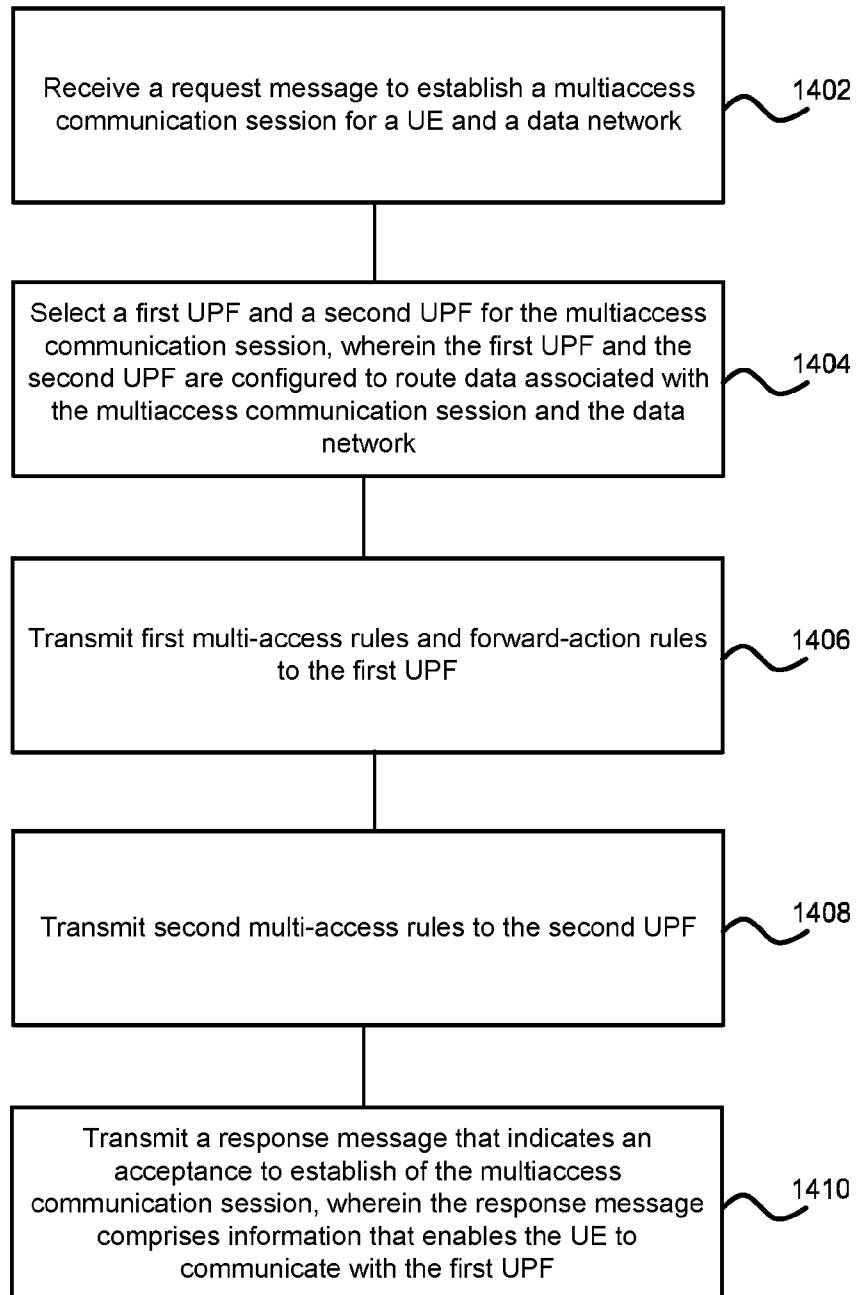


Figure 14

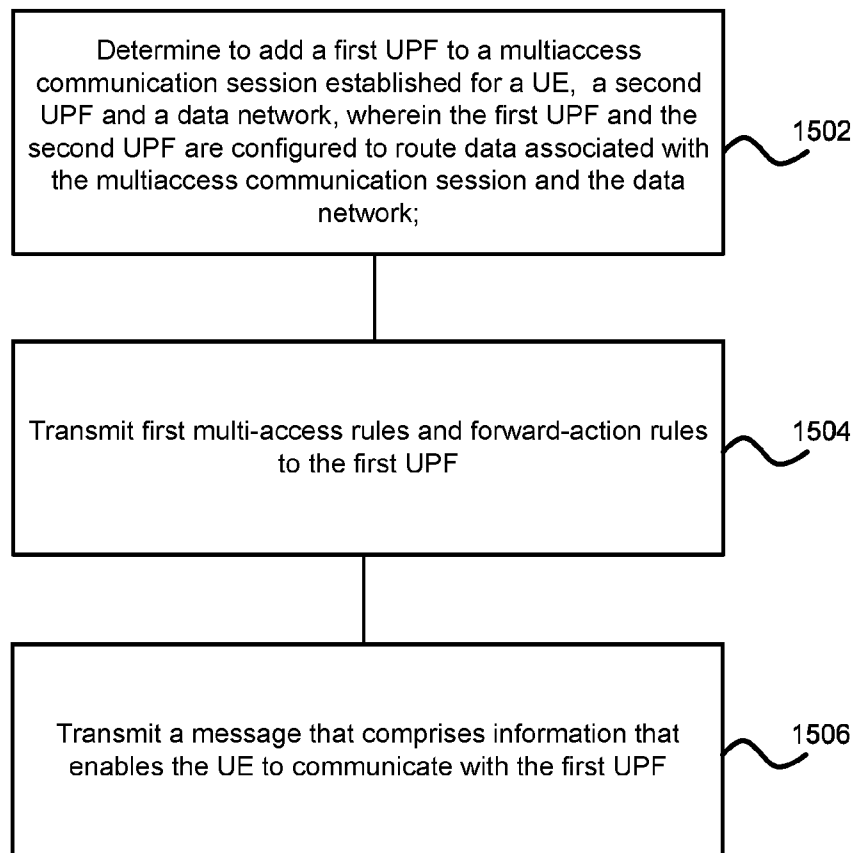


Figure 15

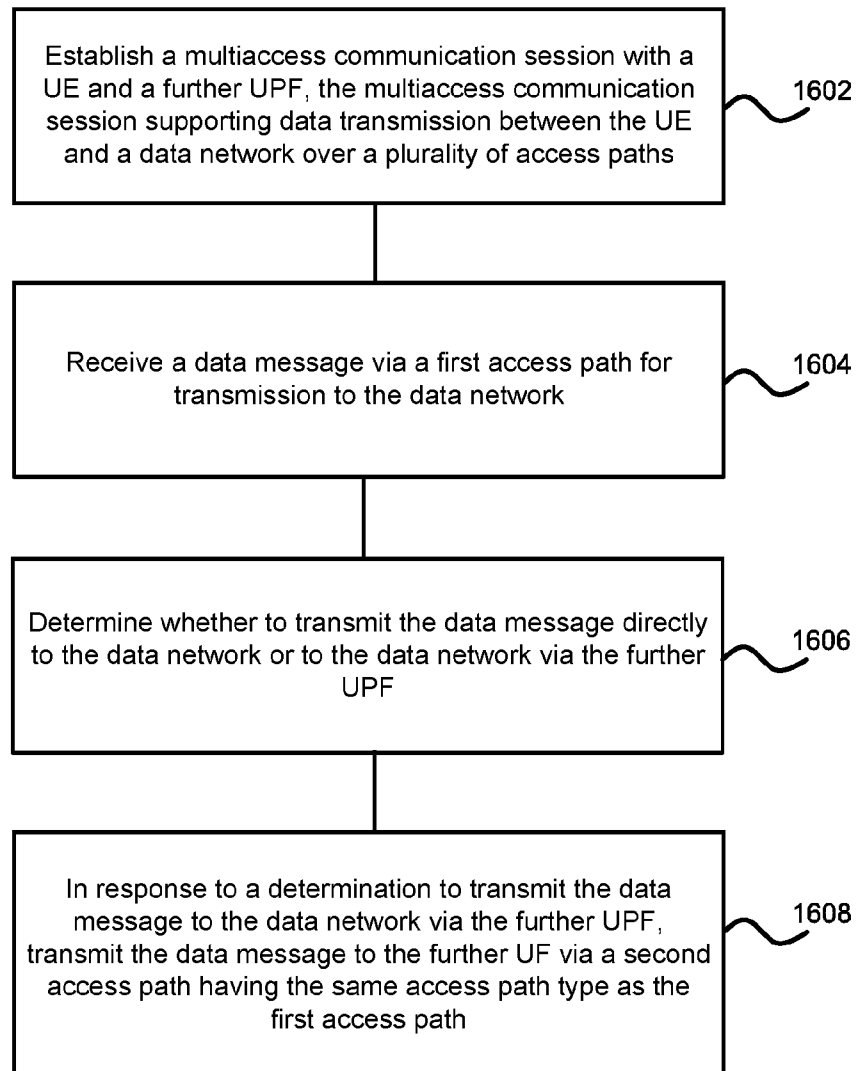


Figure 16

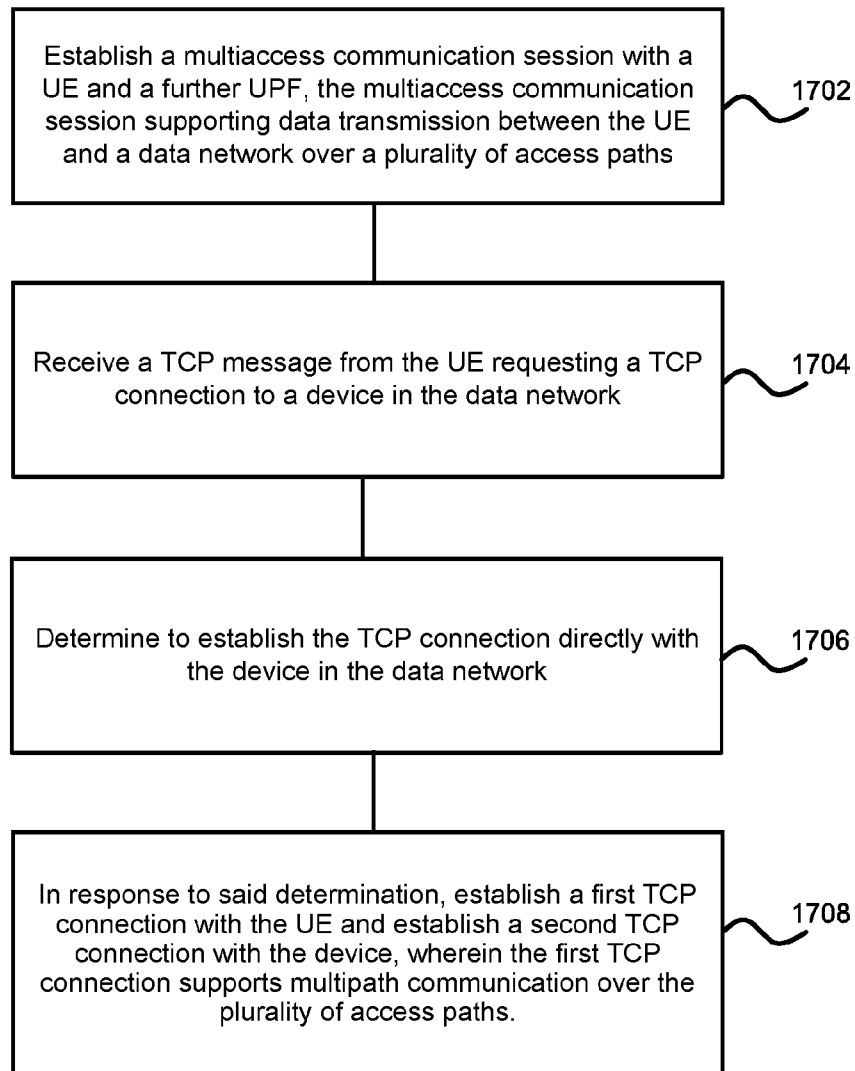


Figure 17

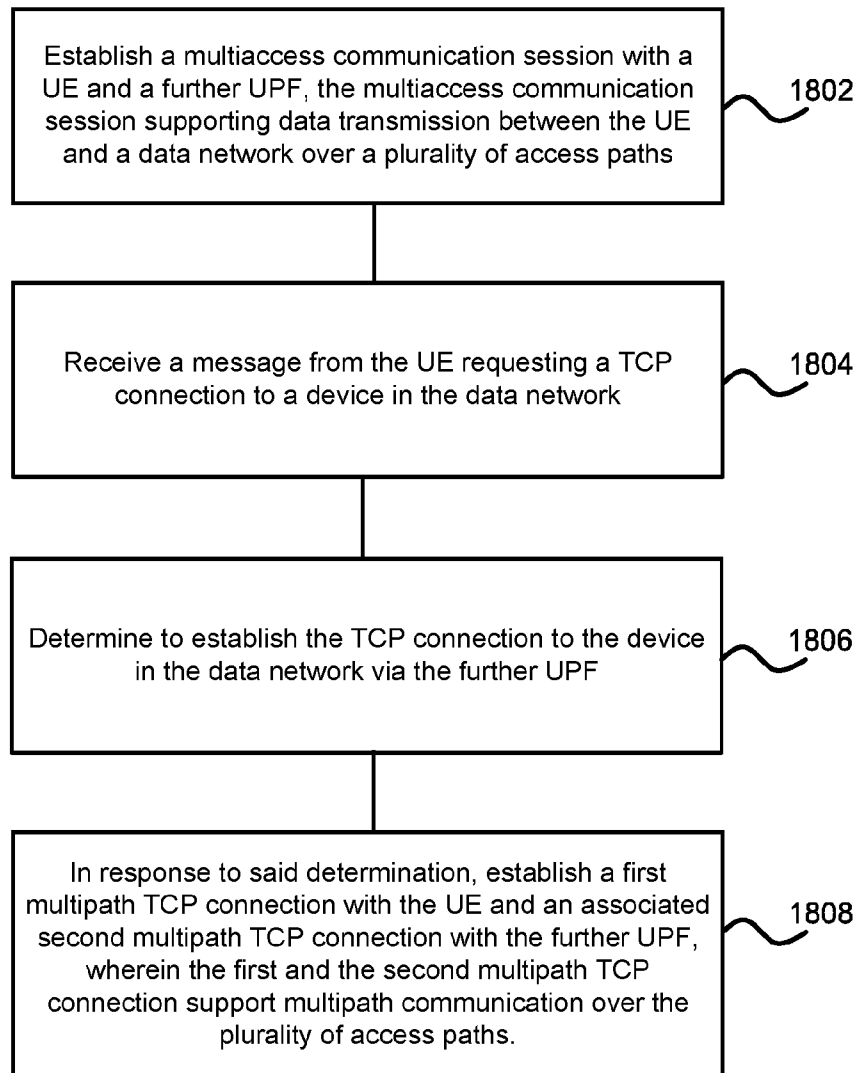


Figure 18

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/080841

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/16

ADD. H04W76/12 H04W76/15

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)

H04W

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	APOSTOLIS SALKINTZIS ET AL: "Introduction of the MPQUIC Steering Functionality", 3GPP DRAFT; S2-2300742; TYPE CR; CR 3973; ATSSS_PH3, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP SA 2, no. Online; 20230116 - 20230120 9 January 2023 (2023-01-09), XP052232211, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_154AHE_Electronic_2023-01/Docs/S2-2300742.zip S2-2300742_23501_ATSSS_Architecture_v4.doc x [retrieved on 2023-01-09] pages 6-12; figures 4.2.10-2,4.2.10-3, -/-	1 - 14



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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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

11 June 2024

Date of mailing of the international search report

20/08/2024

Name and mailing address of the ISA/

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Authorized officer

Alonso Maleta, J

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/080841

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	5.32.6.2.2-1 pages 21,24-26 -----	
A	WO 2023/076773 A1 (QUALCOMM INC [US]) 4 May 2023 (2023-05-04) paragraphs [0094] - [0097]; figure 6 -----	1 - 14
A	EP 4 236 587 A2 (MOTOROLA MOBILITY LLC [US]) 30 August 2023 (2023-08-30) paragraphs [0004] - [0006], [0022], [0033] - [0038], [0042] - [0046], [0056] - [0062]; figures 2,6A, 6B paragraphs [0070] - [0112] -----	1 - 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2023/080841

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.:
1 - 14

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: 1-14

Routing of a data message by a UPF

2. claims: 15-20

Establishment of a TCP connection

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2023/080841

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2023076773 A1	04-05-2023	CN 118160406 A	07-06-2024
		WO 2023076773 A1	04-05-2023

EP 4236587 A2	30-08-2023	BR 112020000662 A2	14-07-2020
		CN 110692281 A	14-01-2020
		CN 117354961 A	05-01-2024
		EP 3653017 A1	20-05-2020
		EP 4236587 A2	30-08-2023
		KR 20200021977 A	02-03-2020
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		US 2019274178 A1	05-09-2019
		US 2021007167 A1	07-01-2021
		US 2022295585 A1	15-09-2022
		WO 2019011398 A1	17-01-2019
