



(51) International Patent Classification:

H04L 12/24 (2006.01) *H04M 15/00* (2006.01)

(21) International Application Number:

PCT/US2017/027460

(22) International Filing Date:

13 April 2017 (13.04.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/353,224	22 June 2016 (22.06.2016)	US
62/375,620	16 August 2016 (16.08.2016)	US

(71) Applicant: INTEL IP CORPORATION [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).

(72) Inventors: SHAN, Chang Hong; 23F, No. 2299, West Yan'an Road, Shanghai 200336 (CN). STOJANOVSKI, Alexandre; 6 villa faucheur, 75020 Paris (FR).

(74) Agent: WEISKOPF, Marie A.; Steel Rives LLP, 760 SW Ninth Avenue, Suite 3000, Portland, Oregon 97205 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) Title: PACKET SWITCH DATA-OFF HANDLING

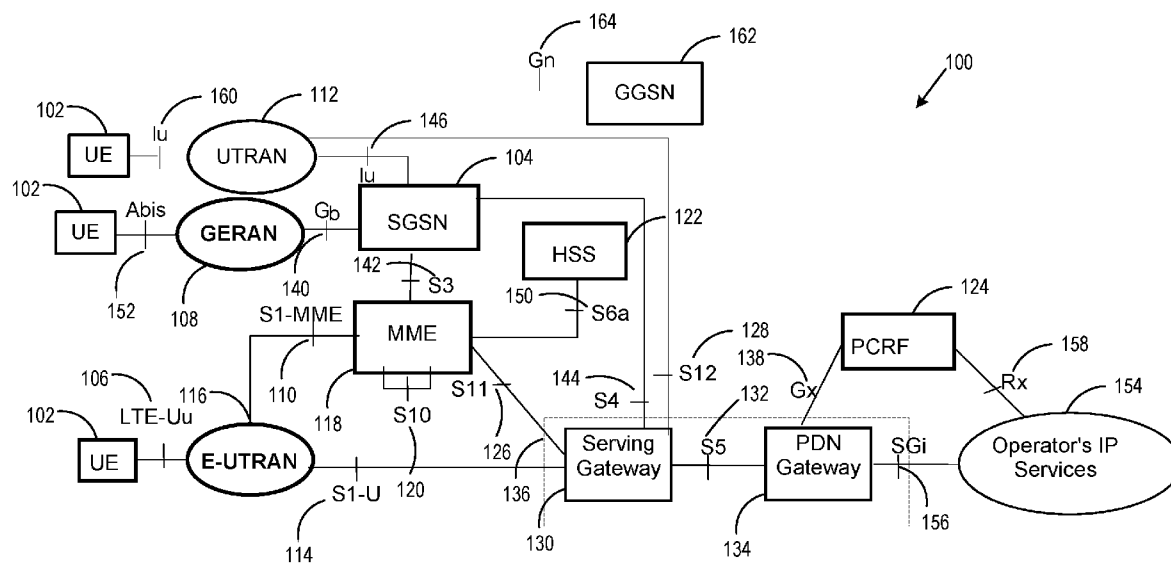


FIG. 1

(57) Abstract: An apparatus for a user equipment (UE) facilitates, in response to a change in a data-off function of the UE, control in a core network over data charges attributable to wireless communications through an evolved universal mobile telecommunications service (UMTS) terrestrial radio access network (E-UTRAN) between the UE and the core network. The apparatus includes processor circuitry configured to (i) process a data-off state to determine whether the data-off state has changed between activated and deactivated states, and (ii) generate for a mobility management entity (MME) a message including the data-off state of the UE, thereby causing a policy and charging enforcement function (PCEF) of the core network to change a charging configuration between suppression and transmission of data from services that incur data charges calculated by data volume. The suppression corresponds to the activated state of the data-off function, and the transmission corresponds to the deactivated state of the data-off function.



(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

- *with international search report (Art. 21(3))*
-

PACKET SWITCH DATA-OFF HANDLING

Related Applications

[0001] This application claims benefit of U.S. Provisional Patent Application No. 62/353,224, filed June 22, 2016, and U.S. Provisional Patent Application No. 62/375,620, filed August 16, 2016. Each application is incorporated by reference herein in its entirety.

Technical Field

[0002] The present disclosure relates generally to the field of wireless communications and, more particularly, to inhibiting data charges when a user equipment is in a data-off state.

Brief Description of the Drawings

[0003] FIG. 1 is a block diagram illustrating a wireless network architecture in accordance with an embodiment.

[0004] FIG. 2 is a sequence diagram illustrating sending information corresponding to a current state of a data-off function of a user equipment (UE) to a packet data network (PDN) gateway (PGW) during an attach procedure.

[0005] FIG. 3 is a sequence diagram illustrating sending information corresponding to a current state of a data-off function of a UE to a PGW during a UE requested PDN connectivity procedure.

[0006] FIG. 4 is a sequence diagram illustrating sending information corresponding to a current state of a data-off function of a UE to a PGW after a PDN connection establishment according to an embodiment.

[0007] FIG. 5 is another sequence diagram illustrating sending information corresponding to a current state of a data-off function of a UE to a PGW after a PDN connection establishment according to another embodiment.

[0008] FIG. 6 is a sequence diagram illustrating sending information corresponding to a current state of a data-off function of a UE to a General Packet Radio Service

(GPRS) Support node (GGSN) after a PDN connection establishment according to another embodiment.

[0009] FIG. 7 is a block diagram illustrating electronic device circuitry that may be UE circuitry, evolved universal terrestrial access network (E-UTRAN) Node B (evolved Node B, eNodeB, or eNB) circuitry, or network node circuitry.

[0010] FIG. 8 is a block diagram illustrating components of a UE device according to one embodiment.

[0011] FIG. 9 is a block diagram illustrating components according to some embodiments.

Detailed Description of Embodiments

[0012] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc., in order to provide a thorough understanding of the various aspects of various embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the various embodiments may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the various embodiments with unnecessary detail.

[0013] With the introduction of always-on internet protocol (IP) connectivity in a 3GPP network, it became difficult for a subscriber to have explicit control of IP traffic sent or received by a user equipment (UE) of the subscriber. This lack of explicit control can lead to unexpected data charges for the subscriber. To give control back to the subscriber, a data-off function has been implemented on the UE. When the data-off function is placed in the activated state by the subscriber on the UE, the data-off function prevents the UE from sending and receiving any uplink or downlink IP traffic to or from the network. However, the data-off function is an implementation-specific feature locally implemented on the UE. As a consequence, there are two main

drawbacks when existing data-off implementation is in the activated state: all packet switched (PS) domain-based services are potentially impacted, and unexpected data charges from downlink IP traffic are possible.

[0014] All PS domain-based services are potentially impacted, since the data-off function needs to take into account that IP Multimedia Subsystem (IMS) services will be used by operators to replace existing circuit switched (CS) services that are currently not impacted when the data-off function is in the activated state on the UE. Taking a straightforward approach of completely disabling all PS user data transfer will result in such IMS services, such as voice calling or messaging services, no longer working while the device is under long term evolution (LTE) network coverage.

[0015] Further, the UE currently does not notify the network when the data-off function is in the activated state. While keeping a packet data network (PDN) connection open, application servers (if the PDN connection provides solely access to an operator's application servers) or Internet hosts (if the PDN connection provides access to the Internet and the operator's application servers) may continue sending downlink IP traffic to the UE without the network being aware that these packets are to be blocked. If the UE does not send any uplink IP packets, then well-managed operator's application servers may close the service session after a while, but Internet hosts might continue to send unsolicited IP packets (e.g., transmission control protocol (TCP) synchronization (SYN) packets, user datagram protocol (UDP) packets, or internet control message protocol (ICMP) packets) to the UE without any time limit. As a consequence, the subscriber will be charged for downlink IP traffic even though the data-off function is in the activated state. This may lead to subscriber complaints due to unexpected charges when the data-off function of the UE is activated.

[0016] FIG. 1 shows a network architecture 100 in accordance with an embodiment. The network architecture 100 may be a Non-Roaming 3GPP Core Network Architecture with three different Radio Access Networks (RANs). The 3GPP Network Architecture 100 may include an Evolved Packet Core (EPC) and a General Packet Radio Service (GPRS) Core, which may be connected with each other by various interfaces, as will be described in more detail below. As shown in FIG. 1, the GPRS Core may include a Serving GPRS Support Node (SGSN) 104, which may be coupled to different RANs,

such as, e.g., to a GSM EDGE Radio Access Network (GERAN) 108 (which may also be referred to as 2G or 2.5G) via a Gb interface 140, and/or to a universal mobile telecommunications service (UMTS) Terrestrial Radio Access Network (UTRAN) 112 via a Iu interface 146. In an embodiment, UTRAN may be a collective term for the NodeBs and Radio Network Controllers (RNCs) which make up the UMTS radio access network. This communications network, commonly referred to as 3G, may carry many traffic types from real-time Circuit Switched to IP-based Packet Switched. The UTRAN 112 may include at least one NodeB that may be connected to at least one RNC. An RNC may provide control functionalities for one or more NodeB(s). A NodeB and an RNC may be the same device, although typical implementations may have a separate RNC located in a central location serving multiple NodeBs. An RNC together with its corresponding NodeBs may be called the Radio Network Subsystem (RNS). There may be more than one RNS provided per UTRAN.

[0017] Furthermore, in an embodiment, the following entities or components may be provided in the general 3GPP Network Architecture 100:

[0018] an evolved UMTS Terrestrial Radio Access Network (E-UTRAN) 116;

[0019] a trusted non-3GPP Internet Protocol (IP) access network and, connected therewith, trusted non-3GPP IP devices – in other words, trusted non-3GPP devices which may access the EPC using the IP stack;

[0020] a Wireless Local Area Network (WLAN) 3GPP IP access network and, connected therewith, Wireless Local Area Network (WLAN) 3GPP IP devices – in other words, WLAN 3GPP devices which may access the EPC using the IP stack;

[0021] a Home Subscriber Server (HSS) 122; and

[0022] a Policy and Charging Rules Function (PCRF) entity 124.

[0023] The E-UTRAN 116 may be understood as being the new 3GPP Radio Access Network for LTE (3.9G). The proposed E-UTRA air interface may use Orthogonal Frequency-Division Multiple Access (OFDMA) for the downlink transmission direction (tower to handset) and Single Carrier frequency division multiple access (FDMA) (SC-FDMA) for the uplink transmission direction (handset to tower). It may employ MIMO (Multiple-Input Multiple-Output) with a plurality of antennas, e.g., with up to four antennas per station. The use of Orthogonal Frequency Division Multiplexing (OFDM)

may enable E-UTRA to be much more flexible in its use of spectrum than the older Code Division Multiple Access (CDMA)-based systems, such as, e.g., UTRAN. OFDM may have a link spectral efficiency greater than CDMA, and when combined with modulation formats such as 64QAM (Quadrature Amplitude Modulation), and techniques as MIMO, E-UTRA may be more efficient than Wideband CDMA (W-CDMA) with High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA).

[0024] Furthermore, as will be described in more detail below, the EPC may include a mobility management entity (MME) 118 and a serving gateway (SGW) 130 (in FIG. 1 shown as separate devices; however, the MME 118 and the SGW 130 may also be implemented in one combined entity), a 3GPP Anchor entity, and a System Architecture Evolution (SAE) Anchor entity.

[0025] In an embodiment, the E-UTRAN 116 may be connected to the SGW 130 via an S1-U interface 114. In an embodiment, the E-UTRAN 116 may be connected to the MME 118 via an S1-MME interface 110.

[0026] In an embodiment, a UE 102 may be connected to the E-UTRAN 116 by an LTE-Uu interface 106. In another embodiment, the UE 102, which may also be referred to as a mobile station (MS) 102, may be connected to the GERAN 108 via an Abis interface 152. In another embodiment, the MS 102 may be connected to the UTRAN 112 via a lu interface 160.

[0027] Furthermore, the trusted non-3GPP IP entity may be connected to the SAE Anchor entity via an S2a interface. In an embodiment, the S2a interface may be based on the Proxy Mobile IPv6 (PMIP) and, in order to support accesses that do not support PMIP, also Mobile IPv4.

[0028] The WLAN entity may include an Evolved Packet Data gateway (ePDG) and a WLAN access network. The ePDG may be connected to the SAE Anchor entity via an S2b interface, which may provide the user plane with related control and mobility support between the ePDG and a PDN gateway (PGW) 134 of the EPC. In an embodiment, the S2b interface may be based on PMIP.

[0029] Furthermore, the SGSN 104 may be connected to the MME 118 in the EPC via an S3 interface 142, which may provide and enable a user and bearer information

exchange for inter-3GPP access network mobility in an idle and/or activated state. In an embodiment, the S3 interface 142 may be based on the GPRS tunneling protocol (GTP) and the Gn interface as it may be provided between SGSNs. The SGSN 104 may further be connected to the 3GPP Anchor entity via an S4 interface, which may provide the user plane with related control and mobility support between the GPRS Core and the 3GPP Anchor function of the SGW 130 and may be based on GTP and a Gn reference point 164 as provided between the SGSN 104 and a GPRS Support node (GGSN) 162.

[0030] The MME 118 and the SGW 130 may be connected to the 3GPP Anchor entity via an S5a interface, and the 3GPP Anchor entity may be connected to the SAE Anchor entity via an S5b interface.

[0031] Furthermore, the HSS 122 may be connected to the MME 118 via an S6a interface 150, which may provide or enable transfer of subscription and authentication data for authenticating/authorizing user access to the evolved system (AAA interface) between the MME 118 and the HSS 122.

[0032] The PCRF entity 124 may be connected to the EPC via an S7 interface, which may provide transfer of Quality of Service (QoS) policy, and policy and charging control (PCC) rules from the PCRF entity 124 to a policy and charging enforcement function (PCEF) in the PGW 134 of the EPC. In some embodiments, the PCEF may be in the GGSN 162 (not shown). In an embodiment, the S7 interface may be based on a Gx interface 138.

[0033] The PCEF in the PGW 134 encompasses policy enforcement and flow based charging control functionalities. The PCEF provides control over user plane traffic handling at the PGW 134 and its QoS. The PCEF also provides service data flow detection and counting, as well as online and offline charging interactions. For service data flows that are under charging control, the PCEF allows the service data flow to pass through the PGW 134 only if there is a corresponding activated PCC rule and a gate status of the corresponding PCC rule is set as open.

[0034] The PCEF selects a PCC rule for each received packet of data by evaluating received packets against service data flow filters of PCC rules. When a packet matches a service data flow filter, the PCC rule for that service data flow is applied. PCC rules

may be dynamic and provisioned by the PCRF entity 124 to the PCEF via the Gx interface 138. These PCC rules may be either predefined in the PCRF entity 124 or dynamically generated by the PCRF entity 124. PCC rules may also be preconfigured in the PCEF and activated or deactivated at any time.

[0035] The PCC rules consist of, among other things, a rule name, a service identifier, service data flow filters, and a gate status. The gate status of the PCC rule indicates whether the service data flow, detected by the service data flow filter, may pass or be discarded in an uplink or downlink direction. The PCEF may change the gate status of the PCC rules.

[0036] In some embodiments, a traffic detection function (TDF) may be included in the core network. The TDF includes application detection and control (AD-C) rules. Similar to a PCEF, the TDF sorts or filters traffic based on its packet or service data flow. The TDF, however, can also redirect, gate, block, or shape traffic by application. In some embodiments, the PCEF and the TDF are co-located on the PGW 134. In other embodiments, the TDF may not be co-located with the PCEF and may be provided in another component of the core network.

[0037] AD-C rules specify traffic redirection instructions, and a valid time limit for specific applications. These rules target individual applications in the PCRF entity 124. Similar to PCC rules, AD-C rules contain a gate status to indicate whether service data flow may pass through or not.

[0038] IP services 154 such as, e.g., 3G IMS, 3G Packet Switches Streaming (PSS), etc., may be provided via an SGi interface 156 to the SAE Anchor entity and/or via an Rx interface 158 to the PCRF entity 124. In an embodiment, the SGi interface 156 may be the interface between the PGW 134 and the packet data network. The packet data network may be an operator-external public or private packet data network or an intra-operator packet data network, e.g., for provision of IP services such as IMS. The SGi interface 156 may correspond to the Gi and Wi interfaces and support any 3GPP or non-3GPP access. The Rx interface 158 may be the interface between the IP services and the PCRF entity 124.

[0039] In various embodiments, the MME 118 may be connected to other MMEs by an S10 interface 120 for MME relocation and MME-to-MME information transfer.

[0040] In various embodiments, the MME 118 may be connected to the SGW 130 by an S11 interface 126.

[0041] In various embodiments, the SGW 130 may be connected to the PGW 134 by an S5 interface 132. In various embodiments, the SGW 130 may be connected to the SGSN 104 by an S4 interface 144. In various embodiments, the SGW 130 may be connected to the UTRAN 112 by an S12 interface 128.

[0042] In various embodiments, the SGW 130 and the PGW 134 may be one functional entity, as indicated by a dashed box 136.

[0043] According to various embodiments, the EPC may include as its subcomponents the MME 118, the SGW 130, and the PGW 134.

[0044] According to various embodiments, the MME 118 may be the key control node for the LTE access network. It may be responsible for idle-mode UE tracking and paging procedures including retransmissions. It may be involved in the bearer activation/deactivation process and may also be responsible for choosing the SGW 130 for the UE 102 at the initial attach and at time of intra-LTE handover involving Core Network (CN) node relocation. It may be responsible for authenticating the user (by interacting with the HSS 122). The Non-Access Stratum (NAS) signaling may terminate at the MME 118 and it may also be responsible for generation and allocation of temporary identities to UEs. It may check the authorization of the UE to camp on the service provider's Public Land Mobile Network (PLMN) and may enforce UE roaming restrictions. The MME 118 may be the termination point in the network for ciphering/integrity protection for NAS signaling and may handle the security key management. Lawful interception of signaling may also be supported by the MME 118. The MME 118 also may provide the control plane function for mobility between LTE and 3GPP technologies with the S3 interface 142 terminating at the MME 118 from the SGSN 104. The MME 118 may terminate the S6a interface 150 towards the HSS 122 for roaming UEs.

[0045] The SGW 130 may route and forward user data packets, while also acting as the mobility anchor for the user plane during inter-eNodeB handovers and as the anchor for mobility between LTE and other 3GPP technologies (for example terminating the S4 interface 144 and relaying the traffic between 2G/3G systems and PGW 134). For idle-

state UEs, the SGW 130 may terminate the downlink (DL) data path and may trigger paging when DL data arrives for the UE. It may manage and store UE contexts, for example parameters of the IP bearer service, and network internal routing information. It may also perform replication of the user traffic in case of lawful interception.

[0046] According to various embodiments, the PGW 134 may provide connectivity from the UE 102 to external packet data networks by being the point of exit and entry of traffic for the UE 102. The UE 102 may have simultaneous connectivity with more than one PGW 134 for accessing multiple PDNs. The PGW 134 may perform policy enforcement, packet filtering for each user, charging support, lawful interception and packet screening (for example, by the PCEF) or various other functions. The PGW may further act as the anchor for mobility between 3GPP and non-3GPP technologies such as WiMAX and 3GPP2 (CDMA 1X and EvDO (Evolution-Data Optimized)).

[0047] To prevent unexpected data charges, the UE 102 should report a data-off function change to the core network. Then the core network elements – for example, the PCEF in the PGW 134 – may act accordingly to discard downlink IP data for all services that incur data charging by data volume, referred to herein as non-exempt services, as discussed in further detail below. This may prevent some unexpected data charges by the subscriber by preventing non-exempt services from sending downlink IP data while the UE 102 is in an activated data-off state. Initially, the UE 102 may process a data-off function and determine whether a state of the data-off function has changed between activated and deactivated states. In response to a change in the data-off state, the UE 102 generates information indicating a current state of the data-off function. For example, the current state may be activated if the UE 102 is set not to receive data, or deactivated if the UE 102 is set to receive data. For example, if the UE 102 is in an “airplane” mode, the data-off state is set to activated. In some embodiments, the information is included in a packet switched (PS) data-off change status report to report the data-off state to the core network.

[0048] FIG. 2 is a sequence diagram 200 for reporting an initial status of the data-off function of the UE 102 to the core network during an attach procedure. The UE 102 sends 202 the information that includes the data-off state of the UE 102 to the MME 118 in an attach request message through the E-UTRAN 116. The MME 118 processes the

information to identify the data-off state, and the MME 118 may store the information to determine at a later time whether the UE 102's data-off state has changed when new information is received. The MME 118 reports 204 the information to all the SGWs 130 serving the PDN connections of the UE 102. The information may be included in a create session request message, for example. The SGWs process the create session request message to identify the information relating to the data-off state, and the SGWs 130 send 206 the information to all the PGWs 134 in a create session request message serving the PDN connections of the UE 102. The PGWs 134 process the create session request message to identify the information to determine whether the data-off function of the UE 102 is in the activated state or deactivated state. The PCEF of the PGW 134 may then change its charging configuration based on the data-off state, as discussed in more detail below.

[0049] FIG. 3 is a sequence diagram 300 for reporting a state of the data-off function of the UE 102 during a UE requested PDN connectivity procedure. The UE 102 sends 302 the information, which includes the data-off state of the UE 102, to the MME 118 in a PDN connectivity request message through the E-UTRAN 116. The MME 118 stores the information to determine at a later time whether the data-off state has changed when a new message arrives at a later time. The MME 118 further reports 304 the information to all the SGWs 130 serving the PDN connections of the UE 102 and includes the information in a create session request message. The SGWs 130 process the create session request message to identify the information, and SGWs 130 send 306 the information to all the PGWs 134 serving the PDN connections of the UE 102 in a create session request message. The PGWs 134 process the create session request message to identify the information and determine whether the data-off function of the UE 102 is in the activated or deactivated state.

[0050] FIG. 4 is a sequence diagram 400 for reporting a status change of a data-off function of the UE 102 after a PDN connection establishment. In this embodiment, as illustrated in FIG. 4, a state of the data-off function is sent in a PS data-off change status report. However, as mentioned above, the state of the data-off function may be sent in various other formats. If a state of the data-off function changes, the UE 102 generates a message including information corresponding to the current data-off state

and sends 402 the information to the MME 118 through the E-UTRAN 116 in a message. The information may be sent in a variety of different messages to the MME 118. For example, in some embodiments, the information may be included in a PDN disconnection request message during a UE requested PDN disconnection procedure. The information may be included in a PDN connectivity request message during a UE requested PDN connectivity procedure to report the status change. In other embodiments, the information may be included in a request bearer resource modification message during a UE requested bearer resource modification procedure. The information may be included in a tracking area update (TAU) request message during a TAU procedure, when there is a change of SGWs 130.

[0051] The MME 118 acknowledges 404 the message by sending an acknowledgement message to the UE 102.

[0052] The MME 118 processes the message to identify the information corresponding to the data-off state. In some embodiments, the MME may determine whether the state of the data-off function of the UE 102 has changed. The MME 118 generates a message including information corresponding to the data-off state to send 406 to the SGW 130. The information may be sent in a variety of different messages to the SGW 130. For example, in some embodiments, the information may be included in a delete session request message during a UE requested PDN disconnection procedure. The information may be included in a create session request message during a UE requested PDN connectivity procedure to report the status change. In other embodiments, the information may be included in a bearer resource command message during a UE requested bearer resource modification procedure. The information may be included in a create session request message during a TAU procedure.

[0053] The SGW 130 acknowledges 408 the message by sending an acknowledgement message to the MME 118. The SGW 130 processes the received message to identify the information corresponding to the data-off state and stores the information.

[0054] The SGW 130 sends 410 a message including the information to the PGW 134. The information may be sent in a variety of different messages to the PGW 134. For example, in some embodiments, the information may be included in a delete

session request message during a UE requested PDN disconnection procedure. The information may be included in a create session request message during a UE requested PDN connectivity procedure to report the status change. In other embodiments, the information may be included in a bearer resource command message during a UE requested bearer resource modification procedure. The information may be included in a modify bearer request message during a TAU procedure.

[0055] The PGW 134 acknowledges the message by sending 412 an acknowledgement message to the SGW 130. The PGW 134 processes the received message to identify the information corresponding to the data-off state and stores the information.

[0056] When the PCEF and/or the TDF of the PGW 134 receives the information, the PCEF and/or the TDF sets a gate status for a PCC rule or AD-C rule, respectively, based on the state of the data-off function of the UE 102 identified in the information. The PCC and AD-C rules may be enhanced to indicate whether the rule is for exempt services or non-exempt services and whether the data-off function is enabled for a particular PCC and AD-C rule. When the PCEF receives the information, the PCEF can set the requisite gate status for non-exempt services. If there is no indication of an exempt or non-exempt service in a PCC rule, the PCC rule may be regarded as a rule for a non-exempt service.

[0057] If the UE 102 data-off function is in the activated state, the PCEF and/or TDF sets a gate status as closed for all PCC and/or AD-C rules for non-exempt services, but does not change the gate status for PCC and/or AD-C rules of exempt services. If the UE 102 data-off function is in the deactivated state in the UE 102, the PCEF and/or TDF sets a gate status as open for all PCC and AD-C rules for non-exempt services.

[0058] Thus, when a packet matching the service data flow filter for a PCC and/or AD-C rule arrives and the gate status for that PCC and/or AD-C rule is open, the PCEF and/or TDF passes the service data flow, and the subscriber will be charged for the data. However, if a packet matching the service data flow filter for a PCC and/or AD-C rule arrives and the gate status for that PCC and/or AD-C rule is closed, the PCEF and/or TDF discards the service data flow, and the subscriber does not incur data charges for the data.

[0059] In some embodiments, as mentioned above, the PCEF and TDF may not be co-located in the PGW 134, and the TDF may be located in another entity of the core network. In such embodiments, the PCEF in the PGW 134 or the PCRF entity 124 notifies the TDF of the state of the data-off function of the UE 102.

[0060] Exempt services may include such services such as MMTel Voice, short message service (SMS) over IMS, unstructured supplementary service data (USSD) over IMS (USSI), MMTel Video, IMS service identified by an IMS communication service identifier, device management over PS, and IMS Supplementary Service configuration via the Ut interface using extensible markup language (XML) configuration access protocol (XCAP). Generally, these services are not charged by data volume, so sending downlink traffic while the UE 102 has its data-off function in the activated state will not result in unexpected charges to the user. Accordingly, all IMS signaling may be treated as exempt services, so a proxy call session control function (P-CSCF) IP address of the IMS service may be part of a service data flow (SDF) descriptor of a PCC rule or AD-C rule for the PCEF and/or TDF to filter to identify such services as exempt.

[0061] The PCRF entity 124 may use the P-CSCF IP address provided at Rx session establishment to derive the PCC and/or AD-C rule and send it to the PCEF and/or TDF via the Gx interface 138.

[0062] For the session data of MMTel Voice, MMTel Video and USSD based Voice/Video services, during session setup, the P-CSCF initiates an Rx session modification procedure, and the corresponding service data flow descriptor, including communication peers' IP addresses, is sent to the PCRF entity 124 via the Rx interface 158. This information is then used by the PCRF entity 124 to create a PCC rule, and the PCC rule is sent to the PCEF in the PGW 134 via the Gx interface 138.

[0063] For device management over PS, IMS Supplementary Service configuration is done via the Ut interface using XCAP and domain name system (DNS) messages. Accordingly, the IP address of device management (DM) server, XCAP server or DNS server can be part of the service data flow descriptor of the PCC rule. For both roaming and non-roaming cases, a transport address of the DM server or XCAP server can be stored as subscriber profile information in the subscriber profile repository (SPR), then

during a IP connectivity access network (IP-CAN) session establishment/modification procedure, such information may be retrieved by the PCRF entity 124 to derive the PCC rules. In other embodiments, as mentioned above, PCC rules may be predefined and stored in all the PCRF entities 124 of a PLMN, then during the IP-CAN session establishment/modification procedure, such a PCC rule can be sent to the PCEF in the PGW 134 by the PCRF entity 124 via the Gx interface 138.

[0064] That is, the PCC rule can be pre-configured in the PCEF, or the PCC rule can be provided dynamically from the PCRF entity 124 to the PCEF using an IP-CAN session establishment procedure.

[0065] During the IP-CAN session establishment procedure, the PCRF entity 124 sends a PCC rule with an indication of an exempt or non-exempt service to the PCEF in the PGW 134.

[0066] During an IP-CAN session modification procedure initiated by the PCRF entity 124, the PCRF entity 124 sends the PCC rule to the PCEF in the PGW 134. The IP-CAN session modification procedure can be triggered by the IMS session setup procedure for the MMTel Voice, MMTel Video, or USSD over IMS for voice/video services to create corresponding dedicated EPS bearers.

[0067] To avoid deep packet inspection in the PCEF of the PGW 134 to differentiate the content carried in IMS signaling, the P-CSCF may take action in some embodiments to block the non-exempt services when the data-off function is in the activated state in the UE 102. Thus, the P-CSCF in the IMS service needs to be notified about the state of the data-off function of the UE 102.

[0068] The P-CSCF may be notified either directly by the UE 102 via IMS signaling or by the PCRF entity 124.

[0069] To enable the PCEF entity 124 to report the data-off state of the UE 102 to the PCRF entity 124 after an IP-CAN session is established, a new event trigger of needs to be defined and provisioned to the PCEF in the PGW 134 in an acknowledge IP CAN session establishment message during the IP-CAN session establishment procedure. Then, if the state of the data-off function of the UE 102 changes, the PCEF notifies the PCRF entity 124 about the state change in an IP-CAN session modification message.

[0070] In some embodiments, the UE 102 may send information corresponding to the data-off state of the UE 102 via the UTRAN 112 to the EPC or via the GERAN 108 to the EPC. Similar to the E-UTRAN 116, the UE 102 may process a data-off function and determine whether the data-off function of the UE 102 has changed between activated and deactivated states. In response to a change, the UE 102 generates a message including information corresponding to the data-off state.

[0071] When the information from the UE 102 is sent via the UTRAN 112 or the GERAN 108 to the EPC, the PCEF may be located in the PGW 134, as discussed above, or the PCEF may be located in the GGSN 162. As such, the information may be ultimately reported to either the PGW 134 or the GGSN 162.

[0072] As seen in one embodiment, depicted in the timing diagram 500 of FIG. 5, the UE 102 sends 502 the information to the SGSN 104 in a message. The SGSN 104 processes the message to identify the information and sends 504 the information to the SGW 130. The SGW sends 506 the information to the PGW 134. The PCEF in the PGW 134 processes the information to identify the data-off state of the UE 102, as discussed above, to set the gate status as open or closed for the PCC or AD-C rules of non-exempt services based on the state of the data-off function in the UE 102.

[0073] As seen in another embodiment, as depicted in the timing diagram 600 of FIG. 6, the UE 102 sends 602 the information to the SGSN 104 in a message. The SGSN 104 processes the message to identify the information and sends 604 the information in a message to the GGSN 162.

[0074] In both FIGS. 5 and 6, the UE 102 may send the information in an attach request message from the UE 102 to the SGSN 104 during a GPRS attach procedure. In some embodiments, the information is included in an activated packet data protocol (PDP) context request message during a PDP context activation procedure. In still other embodiments, the information is included in a routing area update request message during a routing area update procedure. The type of message sent to the SGSN 104 depends on the status of the UE connection within the GERAN 108 or the UTRAN 112. The SGSN 104 may store the information in a memory.

[0075] The SGSN 104 may send the information to the SGW 130 in either a create session request message or a modify bearer request message. The SGW 130 also

reports the information to the PGW 134 in either a create session request message or a modify bearer request message.

[0076] In FIG. 6, the SGSN 104 may send the information to the GGSN 162 in a create PDP context request message during a PDP context activation procedure. In some embodiments, the information may be sent in an intra-SGSN routing area update procedure.

[0077] The PCEF of the PGW 134 handles the information in the same manner as discussed above, and sets the gate status of the PCC and/or AD-C rules based on the data-off state of the UE 102.

[0078] In some embodiments, the UE 102 may be transferred from the E-UTRAN 116 to the UTRAN 112 in an E-UTRAN to UTRAN lu mode inter-radio access technologies (RAT) handover. During the transfer, the MME 118 sends the information to the SGSN 104 rather than the SGW 130, since the UE 102 has moved into the UTRAN 112. During the transfer, the information may be included in a relocation request message or a relocation complete message from the MME 118 to the SGSN 104. The SGSN 104 may store the information identifying the data-off state of the UE 102 and forward the information, as discussed above, to the GGSN 162 or the PGW 134.

[0079] In other embodiments, the UE 102 may be transferred from the UTRAN 112 to the E-UTRAN 116 in a UTRAN lu mode to E-UTRAN inter-RAT handover. During the transfer, the SGSN 104 transfers the information indicating the data-off state of the UE 102 to the MME 118 in a forward relocation request message or a forward relocation complete acknowledgement message. The MME 118 may store the information and may forward the information, as discussed above, to the PGW 134.

[0080] In other embodiments, the UE 102 may be transferred from the E-UTRAN 116 to the GERAN 108 in a GERAN A/Gb mode inter-RAT handover. During the transfer, the SGSN 104 transfers the information identifying the data-off state of the UE 102 to SGSN 104 in a forward relocation request message or a forward relocation complete acknowledgement message. The SGSN 104 then stores the information and may forward the information, as discussed above, to the PGW 134 or the GGSN 162.

[0081] In other embodiments, the UE 102 may be transferred from the GERAN 108 to the E-UTRAN 116 in a GERAN A/Gb mode to E-UTRAN inter-RAT handover. During the transfer, the SGSN 104 transfers the information to the MME 118 in a forward relocation request message or a forward relocation complete acknowledgement message. The MME 118 may store the information and forward it on to the PGW 134 or GGSN 162, as discussed above.

[0081] FIG. 7 is a block diagram illustrating electronic device circuitry 700 that may be eNB circuitry, UE circuitry, network node circuitry, or some other type of circuitry in accordance with various embodiments. In embodiments, the electronic device circuitry 700 may be, or may be incorporated into or otherwise a part of, an eNB, a UE, a network node, or some other type of electronic device. In embodiments, the electronic device circuitry 700 may include radio transmit circuitry 710 and receive circuitry 712 coupled to control circuitry 714. In embodiments, the transmit circuitry 710 and/or the receive circuitry 712 may be elements or modules of transceiver circuitry, as shown. The electronic device circuitry 700 may be coupled with one or more antenna elements 716 of one or more antennas. The electronic device circuitry 700 and/or the components of the electronic device circuitry 700 may be configured to perform operations similar to those described elsewhere in this disclosure.

[0082] As used herein, the term “circuitry” may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0083] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 8 is a block diagram illustrating, for one embodiment, example components of a user equipment (UE) device 800. In some embodiments, the UE device 800 may include application circuitry 802, baseband

circuitry 804, Radio Frequency (RF) circuitry 806, front-end module (FEM) circuitry 808, and one or more antennas 810, coupled together at least as shown in FIG. 8.

[0084] The application circuitry 802 may include one or more application processors. By way of non-limiting example, the application circuitry 802 may include one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processor(s) may be operably coupled and/or include memory/storage, and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0085] By way of non-limiting example, the baseband circuitry 804 may include one or more single-core or multi-core processors. The baseband circuitry 804 may include one or more baseband processors and/or control logic. The baseband circuitry 804 may be configured to process baseband signals received from a receive signal path of the RF circuitry 806. The baseband circuitry 804 may also be configured to generate baseband signals for a transmit signal path of the RF circuitry 806. The baseband circuitry 804 may interface with the application circuitry 802 for generation and processing of the baseband signals, and for controlling operations of the RF circuitry 806.

[0086] By way of non-limiting example, the baseband circuitry 804 may include at least one of a second generation (2G) baseband processor 804A, a third generation (3G) baseband processor 804B, a fourth generation (4G) baseband processor 804C, and other baseband processor(s) 804D for other existing generations and generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 804 (e.g., at least one of the baseband processors 804A-804D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 806. By way of non-limiting example, the radio control functions may include signal modulation/demodulation, encoding/decoding, radio frequency shifting, other functions, and combinations thereof. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 804 may be programmed to perform Fast-Fourier Transform (FFT), precoding, constellation mapping/demapping functions, other functions, and combinations thereof. In some embodiments,

encoding/decoding circuitry of the baseband circuitry 804 may be programmed to perform convolutions, tail-biting convolutions, turbo, Viterbi, Low Density Parity Check (LDPC) encoder/decoder functions, other functions, and combinations thereof.

Embodiments of modulation/demodulation and encoder/decoder functions are not limited to these examples, and may include other suitable functions.

[0087] In some embodiments, the baseband circuitry 804 may include elements of a protocol stack. By way of non-limiting example, elements of an evolved universal terrestrial radio access network (E-UTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 804E of the baseband circuitry 804 may be programmed to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry 804 may include one or more audio digital signal processor(s) (DSP) 804F. The audio DSP(s) 804F may include elements for compression/decompression and echo cancellation. The audio DSP(s) 804F may also include other suitable processing elements.

[0088] The baseband circuitry 804 may further include memory/storage 804G. The memory/storage 804G may include data and/or instructions for operations performed by the processors of the baseband circuitry 804 stored thereon. In some embodiments, the memory/storage 804G may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 804G may also include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. In some embodiments, the memory/storage 804G may be shared among the various processors or dedicated to particular processors.

[0089] Components of the baseband circuitry 804 may be suitably combined in a single chip or a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 804 and the application circuitry 802 may be implemented together, such as, for example, on a system on a chip (SOC).

[0090] In some embodiments, the baseband circuitry 804 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 804 may support communication with an evolved universal terrestrial radio access network (E-UTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), and a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0091] The RF circuitry 806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 806 may include switches, filters, amplifiers, etc., to facilitate the communication with the wireless network. The RF circuitry 806 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 808, and provide baseband signals to the baseband circuitry 804. The RF circuitry 806 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 804, and provide RF output signals to the FEM circuitry 808 for transmission.

[0092] In some embodiments, the RF circuitry 806 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 806 may include mixer circuitry 806A, amplifier circuitry 806B, and filter circuitry 806C. The transmit signal path of the RF circuitry 806 may include the filter circuitry 806C and the mixer circuitry 806A. The RF circuitry 806 may further include synthesizer circuitry 806D configured to synthesize a frequency for use by the mixer circuitry 806A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 806A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 808 based on the synthesized frequency provided by the synthesizer circuitry 806D. The amplifier circuitry 806B may be configured to amplify the down-converted signals.

[0093] The filter circuitry 806C may include a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the

baseband circuitry 804 for further processing. In some embodiments, the output baseband signals may include zero-frequency baseband signals, although this is not a requirement. In some embodiments, the mixer circuitry 806A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0094] In some embodiments, the mixer circuitry 806A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 806D to generate RF output signals for the FEM circuitry 808. The baseband signals may be provided by the baseband circuitry 804 and may be filtered by the filter circuitry 806C. The filter circuitry 806C may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0095] In some embodiments, the mixer circuitry 806A of the receive signal path and the mixer circuitry 806A of the transmit signal path may include two or more mixers, and may be arranged for quadrature downconversion and/or upconversion, respectively. In some embodiments, the mixer circuitry 806A of the receive signal path and the mixer circuitry 806A of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 806A of the receive signal path and the mixer circuitry 806A may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 806A of the receive signal path and the mixer circuitry 806A of the transmit signal path may be configured for super-heterodyne operation.

[0096] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In such embodiments, the RF circuitry 806 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and the baseband circuitry 804 may include a digital baseband interface to communicate with the RF circuitry 806.

[0097] In some dual-mode embodiments, separate radio integrated chip (IC) circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0098] In some embodiments, the synthesizer circuitry 806D may include one or more of a fractional-N synthesizer and a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, the synthesizer circuitry 806D may include a delta-sigma synthesizer, a frequency multiplier, a synthesizer comprising a phase-locked loop with a frequency divider, other synthesizers and combinations thereof.

[0099] The synthesizer circuitry 806D may be configured to synthesize an output frequency for use by the mixer circuitry 806A of the RF circuitry 806 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 806D may be a fractional $N/N+1$ synthesizer.

[0100] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 804 or the application circuitry 802 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the application circuitry 802.

[0101] The synthesizer circuitry 806D of the RF circuitry 806 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may include a dual modulus divider (DMD), and the phase accumulator may include a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In such embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL may provide negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0102] In some embodiments, the synthesizer circuitry 806D may be configured to generate a carrier frequency as the output frequency. In some embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency, etc.) and used in conjunction with a quadrature

generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 806 may include an IQ/polar converter.

[0103] The FEM circuitry 808 may include a receive signal path which may include circuitry configured to operate on RF signals received from the one or more antennas 810, amplify the received signals, and provide the amplified versions of the received signals to the RF circuitry 806 for further processing. The FEM circuitry 808 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 806 for transmission by at least one of the one or more antennas 810.

[0104] In some embodiments, the FEM circuitry 808 may include a TX/RX switch configured to switch between a transmit mode and a receive mode operation. The FEM circuitry 808 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 808 may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 806). The transmit signal path of the FEM circuitry 808 may include a power amplifier (PA) configured to amplify input RF signals (e.g., provided by RF circuitry 806), and one or more filters configured to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 810).

[0105] In some embodiments, the UE device 800 may include additional elements such as, for example, memory/storage, a display, a camera, one or more sensors, an input/output (I/O) interface, other elements, and combinations thereof.

[0106] In some embodiments, the UE device 800 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof.

[0107] FIG. 9 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 9 shows a diagrammatic representation of hardware resources 900 including one or more processors (or

processor cores) 910, one or more memory/storage devices 920, and one or more communication resources 930, all of which are communicatively coupled via a bus 940.

[0108] The processors 910 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 912 and a processor 914. The memory/storage devices 920 may include main memory, disk storage, or any suitable combination thereof.

[0109] The communication resources 930 may include interconnection and/or network interface components or other suitable devices to communicate with one or more peripheral devices 904 and/or one or more databases 906 via a network 908. For example, the communication resources 930 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

[0110] Instructions 950 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 910 to perform any one or more of the methodologies discussed herein. The instructions 950 may reside, completely or partially, within at least one of the processors 910 (e.g., within the processor's cache memory), the memory/storage devices 920, or any suitable combination thereof. Furthermore, any portion of the instructions 950 may be transferred to the hardware resources 900 from any combination of the peripheral devices 904 and/or the databases 906. Accordingly, the memory of processors 910, the memory/storage devices 920, the peripheral devices 904, and the databases 906 are examples of computer-readable and machine-readable media.

[0111] Example 1 is a server for a packet data network (PDN) gateway (PGW). The server has a policy and charging and enforcement function (PCEF) to control, based on a data-off function of a user equipment (UE), data charges calculated by data volume

and attributable to wireless communications through an evolved universal mobile telecommunications service (UMTS) terrestrial radio access network (E-UTRAN). The server includes a memory designed to store a message indicating a current state of the data-off function of the UE. The server includes a processor circuitry designed to process the message to determine the current state of the data-off function of the UE, the data-off function having an activated state and a deactivated state. The server includes a processor circuitry designed to set as closed a gate status of a policy and charging control (PCC) rule to suppress the data charges when the data-off function of the UE is in the activated state by causing downlink data traffic to be discarded. The server includes a processor circuitry designed to set as open the gate status of the PCC rule to allow the data charges when the data-off function of the UE is in the deactivated state by causing downlink data traffic to be transmitted.

[0112] Example 2 is the server of Example 1, where the processor circuitry is further designed to process PCC rules from a policy and charging rules function (PCRF) to determine whether a PCC rule is applicable to a service that incurs the data charges calculated by data volume.

[0113] Example 3 is the server of any one of Examples 1 and 2, where the message is a first message and the processor circuitry is further designed to generate for a policy and charging rules function (PCRF) a second message including information corresponding to the current state of the data-off function of the UE.

[0114] Example 4 is the server of Example 1, where the processor circuitry is further designed to generate an acknowledgement message for a serving gateway (SGW) to acknowledge receipt of the message.

[0115] Example 5 is a computer-readable storage medium. The computer-readable storage medium having instructions stored thereon that, when executed by a processor of a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF), cause the processor to process a message indicating a current state of the data-off function of a user equipment (UE) to determine a current state of a data-off function of the UE, the data-off function having an activated state and a deactivated state. The computer-readable storage medium having instructions stored thereon that, when executed by a processor of a packet data network (PDN) gateway

(PGW) having a policy and charging and enforcement function (PCEF), cause the processor to set as closed a gate status of a policy and charging control (PCC) rule to suppress data charges when the data-off function of the UE is in the activated state by causing downlink data traffic to be discarded. The computer-readable storage medium having instructions stored thereon that, when executed by a processor of a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF), cause the processor to set as open the gate status of the PCC rule to allow the data charges when the data-off function of the UE is in the deactivated state by causing downlink data traffic to be transmitted.

[0116] Example 6 is the computer-readable storage medium of Example 5, where the instructions further cause the processor to process PCC rules from a policy and charging rules function (PCRF) to determine whether a PCC rule is applicable to a service that incurs the data charges calculated by data volume.

[0117] Example 7 is the computer-readable storage medium of any one of Examples 5 and 6, where the message is a first message and the instructions further cause the processor to generate for a policy and charging rules function (PCRF) a second message including information corresponding to the current state of the data-off function of the UE.

[0118] Example 8 is the computer-readable storage medium of Example 5, where the instructions further cause the processor to generate an acknowledgement message for a serving gateway (SGW) to acknowledge receipt of the message.

[0119] Example 9 is an apparatus. The apparatus for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF), including a manner for processing a message indicating a current state of the data-off function of a user equipment (UE) to determine a current state of a data-off function of the UE, the data-off function having an activated state and a deactivated state. The apparatus for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF), including a manner for setting as closed a gate status of a policy and charging control (PCC) rule to suppress data charges when the data-off function of the UE is in the activated state by causing downlink data traffic to be discarded. The apparatus for a packet data network (PDN) gateway (PGW) having

a policy and charging and enforcement function (PCEF), including a manner for setting as open the gate status of the PCC rule to allow the data charges when the data-off function of the UE is in the deactivated state by causing downlink data traffic to be transmitted.

[0120] Example 10 is the apparatus of Example 9, further includes a manner for processing PCC rules from a policy and charging rules function (PCRF) to determine whether a PCC rule is applicable to a service that incurs the data charges calculated by data volume.

[0121] Example 11 is the apparatus of any one of Examples 9 and 10, where the message is a first message and the apparatus further includes a manner for generating for a policy and charging rules function (PCRF) a second message including information corresponding to the current state of the data-off function of the UE.

[0122] Example 12 is the apparatus of Example 11, further includes a manner for generating an acknowledgement message for a serving gateway (SGW) to acknowledge receipt of the message.

[0123] Example 13 is a method. The method is for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF) to control, based on a data-off function of a user equipment (UE), data charges calculated by data volume and attributable to wireless communications through an evolved universal mobile telecommunications service (UMTS) terrestrial radio access network (E-UTRAN). The method includes processing a message indicating a current state of the data-off function of a user equipment (UE) to determine a current state of a data-off function of the UE, the data-off function having an activated state and a deactivated state. The method includes setting as closed a gate status of a policy and charging control (PCC) rule to suppress data charges when the data-off function of the UE is in the activated state by causing downlink data traffic to be discarded, and setting as open the gate status of the PCC rule to allow the data charges when the data-off function of the UE is in the deactivated state by causing downlink data traffic to be transmitted.

[0124] Example 14 is the method of Example 13, further includes processing PCC rules from a policy and charging rules function (PCRF) to determine whether a PCC rule is applicable to a service that incurs the data charges calculated by data volume.

[0125] Example 15 is the method of any one of Examples 13 and 14, where the message is a first message and the method further includes generating for a policy and charging rules function (PCRF) a second message including information corresponding to the current state of the data-off function of the UE.

[0126] Example 16 is the method of Example 13, further includes generating an acknowledgement message for a serving gateway (SGW) to acknowledge receipt of the message.

[0127] Example 17 is a computer-readable storage medium. The computer-readable storage medium having instructions stored thereon that, when executed by a processor of a mobility management entity (MME), cause the processor to process a first message from a user equipment (UE) to identify a current state of a data-off function of the UE. The computer-readable storage medium having instructions stored thereon that, when executed by a processor of a mobility management entity (MME), cause the processor to generate, in response to identifying the current state of the data-off function of the UE, a second message for a serving gateway (SGW), the second message indicating the current state of the data-off function of the UE and causing a policy and charging enforcement function (PCEF) of a core network to change a charging configuration to, based on the current state of the data-off function of the UE, suppress or transmit data from services that incur data charges.

[0128] Example 18 is the computer-readable storage medium of Example 17, where the instructions further cause the processor to process an acknowledgement message from the SGW.

[0129] Example 19 is the computer-readable storage medium of Example 17, where the instructions further cause the processor to generate, in response to the first message, an acknowledgement message for the UE.

[0130] Example 20 is the computer-readable storage medium of any one of Examples 17-19, where the instructions cause the processor to generate the second message as is one of a delete session request message, a create session request message, a bearer resource command message, or a delete session request message.

[0131] Example 21 is a server for a mobility management entity (MME). The MME that, based on a first message received from a user equipment (UE), reports to a

serving gateway (SGW) of a core network a current state of a data-off function of the UE so as to suppress data charges attributable to wireless communications between the UE and the core network, the server includes a memory designed to store the first message, the first message indicating the current state of the data-off function of the UE. The server also includes one or more baseband processors designed to process the first message from a user equipment (UE) to identify the current state of the data-off function of the UE. The server also includes one or more baseband processors designed to generate, in response to identifying the current state of the data-off function of the UE, a second message for a serving gateway (SGW), the second message indicating the current state of the data-off function of the UE and causing a policy and charging enforcement function (PCEF) of a core network to change a charging configuration to, based on the current state of the data-off function of the UE, suppress or transmit data from services that incur data charges.

[0132] Example 22 is the server of Example 21, where the one or more baseband processors are further designed to process an acknowledgement message from the SGW.

[0133] Example 23 is the server of Example 21, where the one or more baseband processors are further designed to generate, in response to the first message, an acknowledgement message for the UE.

[0134] Example 24 is the server of any one of Examples 21-23, where the one or more baseband processors are further designed to generate the second message as is one of a delete session request message, a create session request message, a bearer resource command message, or a delete session request message.

[0135] Example 25 is an apparatus for a mobility management entity (MME). The MME includes a manner for processing a first message from a user equipment (UE) to identify a current state of a data-off function of the UE. The MME includes a manner for generating, in response to identifying the current state of the data-off function of the UE, a second message for a serving gateway (SGW), the second message indicating the current state of the data-off function of the UE and causing a policy and charging enforcement function (PCEF) of a core network to change a charging configuration to,

based on the current state of the data-off function of the UE, suppress or transmit data from services that incur data charges.

[0136] Example 26 is the apparatus of Example 25, further includes a manner for processing an acknowledgement message from the SGW.

[0137] Example 27 is the apparatus of Example 25, further includes a manner for generating, in response to the first message, an acknowledgement message for the UE.

[0138] Example 28 is the apparatus of any one of Examples 25-27, where the second message is one of a delete session request message, a create session request message, a bearer resource command message, or a delete session request message.

[0139] Example 29 is a method for a mobility management entity (MME) to report, based on a first message received from a user equipment (UE), to a serving gateway (SGW) of a core network a current state of a data-off function of the UE so as to suppress data charges attributable to wireless communications between the UE and the core network. The method includes processing a first message from a user equipment (UE) to identify a current state of a data-off function of the UE. The method also includes generating, in response to identifying the current state of the data-off function of the UE, a second message for a serving gateway (SGW), the second message indicating the current state of the data-off function of the UE and causing a policy and charging enforcement function (PCEF) of a core network to change a charging configuration to, based on the current state of the data-off function of the UE, suppress or transmit data from services that incur data charges.

[0140] Example 30 is the method of Example 29, further includes processing an acknowledgement message from the SGW.

[0141] Example 31 is the method of Example 29, further includes generating, in response to the first message, an acknowledgement message for the UE.

[0142] Example 32 is the method of any one of Examples 29-31, where the second message is one of a delete session request message, a create session request message, a bearer resource command message, or a delete session request message.

[0143] Example 33 is a computer-readable storage medium having instructions stored thereon that, when executed by a processor of a user equipment (UE), cause the processor to determine a current state of a data-off setting. A computer-readable

storage medium having instructions stored thereon that, when executed by a processor of a user equipment (UE), cause the processor to generate for a mobility management entity (MME) a report including the current state of the data-off setting and thereby cause a policy and charging enforcement function (PCEF) of a core network to change a charging configuration between suppressions and transmission of data from services that incur volume-based data charges, the suppression and the transmission corresponding to, respectively, activated and deactivated states of the data-off setting.

[0144] Example 34 is the computer-readable medium of Example 33, where the instructions cause the processor to generate the report in a non-access stratum (NAS) message.

[0145] Example 35 is the computer-readable medium of Example 33, where the instructions cause the processor to generate the report in one of a session indication protocol (SIP) register message, an attach request message, a packet data network (PDN) connectivity request message, a request bearer resource modification message, or a tracking area update (TAU) message.

[0146] Example 36 is the computer-readable medium of Example 33, where the instructions cause the processor to process an acknowledgement message from the MME.

[0147] Example 37 is the computer-readable medium of Example 33, where the report includes a packet switched (PS) data-off change status report generated in response to a change in the current state of the data-off setting of the UE.

[0148] Example 38 is the computer-readable medium of any one of Examples 33-37, where the report is a first message and the where the instructions cause the processor to generate for a proxy call session control function (P-CSCF) a second message including the current state of the data-off setting of the UE.

[0149] Example 39 is an apparatus for a user equipment (UE). The apparatus for a UE is for facilitating, in response to a change in a data-off setting of the UE, control in a core network over volume-based data charges attributable to wireless communications between the UE and the core network, the wireless communications for communication through an evolved universal mobile telecommunications service (UMTS) terrestrial radio access network (E-UTRAN). The apparatus includes a memory designed to store

a current state of the data-off setting having activated and deactivated states. The apparatus includes a baseband processor to determine the current state of the data-off setting, and generate for a mobility management entity (MME) a report including the current state of the data-off setting of the UE and thereby cause a policy and charging enforcement function (PCEF) of the core network to change a charging configuration between suppressions and transmission of data from services that incur the volume-based data charges, the suppression and the transmission corresponding to, respectively, the activated and deactivated states of the data-off setting.

[0150] Example 40 is the apparatus of Example 39, where the report is included in a non-access stratum (NAS) message.

[0151] Example 41 is the apparatus of Example 39, where the report is included in one of a session indication protocol (SIP) register message, an attach request message, a packet data network (PDN) connectivity request message, a request bearer resource modification message, or a tracking area update (TAU) message.

[0152] Example 42 is the apparatus of Example 39, where the baseband processor is designed to process an acknowledgement message from the MME.

[0153] Example 43 is the apparatus of Example 39, where the report includes a packet switched (PS) data-off change status report generated in response to a change in the current state of the data-off setting of the UE.

[0154] Example 44 is the apparatus of any one of Examples 39–43, where the report is a first message and the baseband processor is designed to generate for a proxy call session control function (P-CSCF) a second message including the current state of the data-off setting of the UE.

[0155] Example 45 is an apparatus for a user equipment (UE). The apparatus includes a manner for determining a current state of a data-off setting, and a manner for generating for a mobility management entity (MME) a report including the current state of the data-off setting and thereby cause a policy and charging enforcement function (PCEF) of a core network to change a charging configuration between suppressions and transmission of data from services that incur volume-based data charges, the suppression and the transmission corresponding to, respectively, activated and deactivated states of the data-off setting.

[0156] Example 46 is the apparatus of Example 45, further includes a manner for generating the report in a non-access stratum (NAS) message.

[0157] Example 47 is the apparatus of Example 45, where the report is include in one of a session indication protocol (SIP) register message, an attach request message, a packet data network (PDN) connectivity request message, a request bearer resource modification message, or a tracking area update (TAU) message.

[0158] Example 48 is the apparatus of Example 45, further includes a manner for processing an acknowledgement message from the MME.

[0159] Example 49 is the apparatus of Example 45, where the report includes a packet switched (PS) data-off change status report generated in response to a change in the current state of the data-off setting of the UE.

[0160] Example 50 is the apparatus of any one of Examples 45-49, where the report is a first message and the apparatus further includes manner for generating for a proxy call session control function (P-CSCF) a second message including the current state of the data-off setting of the UE.

[0161] Example 51 is a method for for facilitating, in response to a change in a data-off setting of a user equipment (UE), control in a core network over volume-based data charges attributable to wireless communications between the UE and the core network, the wireless communications for communication through an evolved universal mobile telecommunications service (UMTS) terrestrial radio access network (E-UTRAN). The apparatus includes determining the current state of the data-off setting. The apparatus includes generating for a mobility management entity (MME) a report including the current state of the data-off setting and thereby cause a policy and charging enforcement function (PCEF) of the core network to change a charging configuration between suppressions and transmission of data from services that incur volume-based data charges, the suppression and the transmission corresponding to, respectively, activated and deactivated states of the data-off setting.

[0162] Example 52 is the method of Example 51, further includes generating the report in a non-access stratum (NAS) message.

[0163]

[0164] Example 53 is the method of Example 51, where the report is include in one of a session indication protocol (SIP) register message, an attach request message, a packet data network (PDN) connectivity request message, a request bearer resource modification message, or a tracking area update (TAU) message.

[0165] Example 54 is the method of Example 51, further includes processing an acknowledgement message from the MME.

[0166] Example 55 is the method of Example 51, where the report includes a packet switched (PS) data-off change status report generated in response to a change in the current state of the data-off setting of the UE.

[0167] Example 56 is the method of any one of Examples 51-55, where the report is a first message and the apparatus further includes generating for a proxy call session control function (P-CSCF) a second message including the current state of the data-off setting of the UE.

[0168] Example 57 is a server for a serving gateway (SGW). The server for a SGW is based on a first message received from a mobility management entity (MME), reports to a packet data network (PDN) gateway (PGW) of a core network a current state of a data-off function of a user equipment (UE) so as to suppress data charges attributable to wireless communications between the UE and the core network. The server includes a memory designed to store the first message, the first message indicating the current state of the data-off function of the UE. The server includes processor circuitry designed to process the first message to identify the current state of the data-off function of the UE. The server includes processor circuitry designed to in response to identifying a change of the data-off function , generate a second message indicating the current state the PGW and thereby cause a policy and charging enforcement function (PCEF) of the PGW to update, based on the current state, a charging configuration between suppression and transmission of data from services that incur the data charges.

[0169] Example 58 is the server of Example 57, where the processor circuitry is further designed to process an acknowledgement message from the PGW to confirm receipt of the second message by the PGW.

[0170] Example 59 is the server of Example 57, where the processor circuitry is further designed to generate an acknowledgement message for the MME.

[0171] Example 60 is the server of any one of Examples 57-59, where the second message is a delete session request message.

[0172] Example 61 is the server of any one of Examples 57-59, where the second message is a create session request message.

[0173] Example 62 is the server of any one of Examples 57-59, where the second message is a bearer resource command message.

[0174] Example 63 is the server of any one of Examples 57-59, where the second message is a modify bearer resource command message.

[0175] Example 64 is a method for a serving gateway (SGW) to, based on a first message received from a mobility management entity (MME), report to a packet data network (PDN) gateway (PGW) of a core network a current state of a data-off function of a user equipment (UE) so as to suppress data charges attributable to wireless communications between the UE and the core network. The method includes processing the first message to identify a current state of a data-off function of a UE. The method includes in response to identifying a change of the data-off function, generating a second message indicating the current state the PGW and thereby cause a policy and charging enforcement function (PCEF) of the PGW to update, based on the current state, a charging configuration between suppression and transmission of data from services that incur the data charges.

[0176] Example 65 is the method of Example 57, further includes processing an acknowledgement message from the PGW to confirm receipt of the second message by the PGW.

[0177] Example 66 is the method of Example 57, further includes generating an acknowledgement message for the MME.

[0178] Example 67 is the method of any one of Examples 57-59, where the second message is a delete session request message.

[0179] Example 68 is the method of any one of Examples 57-59, where the second message is a create session request message.

[0180] Example 69 is the method of any one of Examples 57-59, where the second message is a bearer resource command message.

[0181] Example 70 is the method of any one of Examples 57-59, where the second message is a modify bearer resource command message.

[0182] Example 71 is a computer-readable storage medium having instructions stored thereon that, when executed by a processor of the MME, cause the processor to perform the method of any one of Examples 57-70.

[0183] Example 72 is an apparatus for the MME, the apparatus including manner for performing the method of any one of Examples 57-70.

[0184] Example 73 is an apparatus for a server having a policy and charging rules function (PCRF) to facilitate control over data charges calculated by data volume and attributable to wireless communications between a user equipment (UE) and a core network. The server includes a memory designed to store a message including information corresponding to a state of a data-off function of a user equipment (UE). The server includes processor circuitry designed to process the message to identify from the information the state of the data-off function of the UE. The server includes processor circuitry designed to generate, in response to identifying the state of the data-off function of the UE, a second message for a proxy call session control function (P-CSCF) including the information and thereby cause the P-CSCF to change, based on the state of the data-off function of the UE, a charging configuration between suppression and transmission of data from services that incur the data charges calculated by data volume. The server includes processor circuitry designed to generate a policy and charging control (PCC) rule for a policy and charging enforcement function (PCEF) indicating whether a service incurs the data charges calculated by data volume.

[0185] Example 74 is the apparatus of Example 73, where the PCC rule provides for the service a dataflow descriptor that indicates whether the service incurs the data charges calculated by data volume.

[0186] Example 75 is the apparatus of Example 74, where the dataflow descriptor includes an internet protocol (IP) address of the P-CSCF to indicate whether the service incurs charges by data volume.

[0187] Example 76 is the apparatus of Example 74, where the dataflow descriptor includes an internet protocol (IP) address of a device management (DM) server, an extensible markup language (XML) configuration access protocol (XCAP) server, or a domain name system (DNS) server.

[0188] Example 77 is the apparatus of Example 73, where the processor circuitry is further designed to generate the PCC rule to transmit over a Gx interface to a packet data network (PDN) gateway (PGW).

[0189] Example 78 is the apparatus of any one of Examples 73-77, where the processor circuitry is further designed to generate the PCC rule based on a transport address of a device management (DM) server or an extensible markup language (XML) configuration access protocol (XCAP) server.

[0190] Example 79 is a method for a policy and charging rules function (PCRF) to facilitate control over data charges calculated by data volume and attributable to wireless communications between a user equipment (UE) and a core network. The method includes processing a message to identify a state of a data-off function of a UE. The method includes generating, in response to identifying the state of the data-off function of the UE, a second message for a proxy call session control function (P-CSCF) including the state of the data-off function and thereby cause the P-CSCF to change, based on the state of the data-off function of the UE, a charging configuration between suppression and transmission of data from services that incur the data charges calculated by data volume. The method includes generating a policy and charging control (PCC) rule for a policy and charging enforcement function (PCEF) indicating whether a service incurs the data charges calculated by data volume.

[0191] Example 80 is the method of Example 73, where the PCC rule provides for the service a dataflow descriptor that indicates whether the service incurs the data charges calculated by data volume.

[0192] Example 81 is the method of Example 74, where the dataflow descriptor includes an internet protocol (IP) address of the P-CSCF to indicate whether the service incurs charges by data volume.

[0193] Example 82 is the method of Example 74, where the dataflow descriptor includes an internet protocol (IP) address of a device management (DM) server, an

extensible markup language (XML) configuration access protocol (XCAP) server, or a domain name system (DNS) server.

[0194] Example 83 is the method of Example 73, further includes generating the PCC rule to transmit over a Gx interface to a packet data network (PDN) gateway (PGW).

[0195] Example 84 is the method of any one of Examples 73-77, further includes generating the PCC rule based on a transport address of a device management (DM) server or an extensible markup language (XML) configuration access protocol (XCAP) server.

[0196] Example 85 is a computer-readable storage medium having instructions stored thereon that, when executed by a processor of the PCRF, cause the processor to perform the method of any one of Examples 79-84.

[0197] Example 86 is an apparatus for the PCRF, the apparatus including manner for performing the method of any one of Examples 79-84.

[0198] Example 87 is an apparatus for a mobile station (MS) for facilitating, in response to a change in a data-off state of the MS, control in a core network over data charges assessable by data volume and attributable to wireless communications between the MS and the core network, the wireless communications for communication through at least one of a global system for mobile communications evolution radio access network (GERAN) or a universal terrestrial radio access network (UTRAN). The apparatus includes a memory designed to store the data-off state having activated and deactivated states. The apparatus includes a baseband processor to determine whether the data-off state has changed between the activated and deactivated states. The apparatus includes a baseband processor to in response to the change, generate for a serving general packet radio service (GPRS) support node (SGSN) of the core network a packet switched (PS) data-off change status report, the PS data-off change status report indicating to the SGSN a current state of the data-off state and causing a policy charging and enforcement function (PCEF) of the core network to change a charging configuration between suppression and transmission of data from services that incur the data charges assessable by data volume, the suppression and the

transmission corresponding to the PS data-off change status report indicating that the current state is in, respectively, the activated state and the deactivated state.

[0199] Example 88 is the apparatus of Example 87, where the PS data-off change status report is included in an attach request message.

[0200] Example 89 is the apparatus of Example 87, where the PS data-off change status report is included in an activate packet data protocol (PDP) context request message.

[0201] Example 90 is the apparatus of Example 87, where PS data-off change status report is included in a routing area update request message.

[0202] Example 91 is a method for a mobile station (MS) to facilitate, in response to a change in a data-off state of the MS, control in a core network over data charges assessable by data volume and attributable to wireless communications between the MS and the core network, the wireless communications for communication through at least one of a global system for mobile communications evolution radio access network (GERAN) or a universal terrestrial radio access network (UTRAN). The method includes determining whether the data-off state has changed between the activated and deactivated states. The method includes in response to the change, generating for a serving general packet radio service (GPRS) support node (SGSN) of the core network a packet switched (PS) data-off change status report, the PS data-off change status report indicating to the SGSN a current state of the data-off state and causing a policy charging and enforcement function (PCEF) of the core network to change a charging configuration between suppression and transmission of data from services that incur the data charges assessable by data volume, the suppression and the transmission corresponding to the PS data-off change status report indicating that the current state is in, respectively, the activated state and the deactivated state.

[0203] Example 92 is the method of Example 91, where the PS data-off change status report is included in an attach request message.

[0204] Example 93 is the method of Example 91, where the PS data-off change status report is included in an activate packet data protocol (PDP) context request message.

[0205] Example 94 is the method of Example 91, where PS data-off change status report is included in a routing area update request message.

[0206] Example 95 is a computer-readable storage medium having instructions stored thereon that, when executed by a processor of the MS, cause the processor to perform the method of any one of Examples 91-94.

[0207]

[0208] Example 96 is an apparatus for the MS, the apparatus including manner for performing the method of any one of Examples 91-94.

[0209] Example 97 is a computer-readable storage medium having instructions stored thereon that, when executed by a processor of a serving general packet radio service (GPRS) support node (SGSN), cause the processor to process a first message from a mobile station (MS) to identify information corresponding to a current state of a data-off state of the MS. A computer-readable storage medium having instructions stored thereon that, when executed by a processor of a serving general packet radio service (GPRS) support node (SGSN), cause the processor to in response to identifying the current state from the information, generate a second message that provides the current state to a serving gateway (SGW) or a gateway general packet radio service (GPRS) support node (GGSN) and causes a policy charging and enforcement function (PCEF) of a packet data network (PDN) gateway (PGW) or the GGSN to change, based on the current state, a charging configuration between suppression and transmission of data from services that incur data charges assessable by data volume.

[0210] Example 98 is the computer-readable storage medium of Example 97, where the instructions cause the processor to generate the second message as a create session request message.

[0211] Example 99 is the computer-readable storage medium of Example 97, where instructions cause the processor to generate the second message as a modify bearer request message.

[0212] Example 100 is the computer-readable storage medium of Example 97, where the instructions cause the processor to generate the second message as a create packet data protocol (PDP) context request message.

[0213] Example 101 is the computer-readable storage medium of Example 97, where instructions cause the processor to generate the second message as is an update packet data protocol (PDP) context request message.

[0214] Example 102 is the computer-readable storage medium of any one of Examples 97-101, where the second message includes a packet switched (PS) data-off change status report to provide the current state of the data-off state of the MS.

[0215] Example 103. A computer-readable storage medium having instructions stored thereon that, when executed by a processor of a serving general packet radio service (GPRS) support node (SGSN), cause the processor to process a first message from a mobile station (MS) to identify information corresponding to a current state of a data-off state of the MS. A computer-readable storage medium having instructions stored thereon that, when executed by a processor of a serving general packet radio service (GPRS) support node (SGSN), cause the processor to in response to identifying the current state from the information, generate a second message that provides the current state to a serving gateway (SGW) or a gateway general packet radio service (GPRS) support node (GGSN) and causes a policy charging and enforcement function (PCEF) of a packet data network (PDN) gateway (PGW) or the GGSN to change, based on the current state, a charging configuration between suppression and transmission of data from services that incur data charges assessable by data volume.

[0216] Example 104 is the computer-readable storage medium of Example 103, where the instructions cause the processor to generate the second message as a create session request message.

[0217] Example 105 is the computer-readable storage medium of Example 103, where instructions cause the processor to generate the second message as a modify bearer request message.

[0218] Example 106 is the computer-readable storage medium of Example 103, where the instructions cause the processor to generate the second message as a create packet data protocol (PDP) context request message.

[0219] Example 107 is the computer-readable storage medium of Example 103, where instructions cause the processor to generate the second message as an update packet data protocol (PDP) context request message.

[0220] Example 108. The computer-readable storage medium of any one of Examples 103–107, where the second message includes a packet switched (PS) data-off change status report to provide the current state of the data-off state of the MS.

[0221] Example 109. An apparatus for a server having a serving general packet radio service (GPRS) support node (SGSN). The apparatus includes a memory designed to store a message including information corresponding to a state of a data-off function of a mobile station (MS) one or more baseband processors designed to process a first message from the MS to identify information corresponding to a current state of the data-off function of the MS. The apparatus includes a memory designed to store a message including information corresponding to a state of a data-off function of a mobile station (MS) one or more baseband processors designed to in response to identifying the current state from the information, generate a second message that provides the current state to a serving gateway (SGW) or a gateway general packet radio service (GPRS) support node (GGSN) and causes a policy charging and enforcement function (PCEF) of a packet data network (PDN) gateway (PGW) or the GGSN to change, based on the current state, a charging configuration between suppression and transmission of data from services that incur data charges assessable by data volume.

[0222] Example 110 is the apparatus of Example 109, where the second message is a create session request message.

[0223] Example 111 is the apparatus of Example 109, where the second message is a modify bearer request message.

[0224] Example 112 is the apparatus of Example 109, where the second message is a create packet data protocol (PDP) context request message.

[0225] Example 113 is the apparatus of Example 109, where the second message is an update packet data protocol (PDP) context request message.

[0226] Example 114 is the apparatus of any one of Examples 109–113, where the second message includes a packet switched (PS) data-off change status report to provide the current state of the data-off state of the MS.

[0227] Example 115 is a method for a serving general packet radio service (GPRS) support node (SGSN). The method includes processing a first message from a mobile

station (MS) to identify information corresponding to a current state of a data-off state of the MS. The method includes in response to identifying the current state from the information, generating a second message that provides the current state to a serving gateway (SGW) or a gateway general packet radio service (GPRS) support node (GGSN) and causes a policy charging and enforcement function (PCEF) of a packet data network (PDN) gateway (PGW) or the GGSN to change, based on the current state, a charging configuration between suppression and transmission of data from services that incur data charges assessable by data volume.

[0228] Example 116 is the method of Example 115, where the second message is a create session request message.

[0229] Example 117 is the method of Example 115, where the second message is a modify bearer request message.

[0230] Example 118 is the method of Example 115, where the second message is a create packet data protocol (PDP) context request message.

[0231] Example 119 is the method of Example 115, where the second message is an update packet data protocol (PDP) context request message.

[0232] Example 120 is the method of any one of Examples 115–119, where the second message includes a packet switched (PS) data-off change status report to provide the current state of the data-off state of the MS.

[0233] Example 121 is an apparatus for the SGSN, the apparatus including manner for performing the method of any one of Examples 115-120.

[0234] Example 122 is a server for an entity having a policy and enforcement function (PCEF) that controls data charges associated with at least one of a global system for mobile communications evolution radio access network (GERAN) or a universal terrestrial radio access network (UTRAN). The server includes a memory designed to store a message including information corresponding to a data-off state of a mobile station (MS), the data-off state having activated and deactivated states. The server includes processor circuitry designed to process the message to determine from the information the data-off state of the MS, and when the data-off state of the MS is determined as being in the activated state, set as closed a gate status of a policy and charging control (PCC) rule to cause downlink data traffic to be discarded for services

that incur data charges assessable by data volume. The server includes processor circuitry designed to when the data-off state of the MS is determined as being in the deactivated state, set the gate status of the PCC rule as open to cause downlink data traffic to be transmitted for services that incur data charges assessable by data volume.

[0235] Example 123 is the server of Example 122, where the entity is a gateway general packet radio service (GPRS) support node (GGSN).

[0236] Example 124 is the server of Example 123, where the message is a create packet data protocol (PDP) context request message from a serving general packet radio service (GPRS) support node (SGSN).

[0237] Example 125 is the server of Example 123, where the message is an update packet data protocol (PDP) context request message from a serving general packet radio service (GPRS) support node (SGSN).

[0238] Example 126 is the server of Example 122, where the entity is a packet data network (PDN) gateway (PGW).

[0239] Example 127 is the server of Example 126, where the message is a create session request message from a serving gateway (SGW).

[0240] Example 128 is the server of Example 126, where the message is a modify bearer request message from a serving gateway (SGW).

[0241] Example 129 is the server of any one of Examples 122–128, where the information includes a packet switched (PS) data-off change status report.

[0242] Example 130 is a method for an entity having a policy and enforcement function (PCEF) that controls data charges associated with at least one of a global system for mobile communications evolution radio access network (GERAN) or a universal terrestrial radio access network (UTRAN). The method includes processing a message to determine a data-off state of a mobile station (MS), and when the data-off state of the MS is determined as being in an activated state, set as closed a gate status of a policy and charging control (PCC) rule to cause downlink data traffic to be discarded for services that incur data charges assessable by data volume. The method includes when the data-off state of the MS is determined as being in a deactivated state, set the gate status of the PCC rule as open to cause downlink data traffic to be transmitted for services that incur data charges assessable by data volume.

[0243] Example 131 is the method of Example 130, where the entity is a gateway general packet radio service (GPRS) support node (GGSN).

[0244] Example 132 is the method of Example 131, where the message is a create packet data protocol (PDP) context request message from a serving general packet radio service (GPRS) support node (SGSN).

[0245] Example 133 is the method of Example 131, where the message is an update packet data protocol (PDP) context request message from a serving general packet radio service (GPRS) support node (SGSN).

[0246] Example 134 is the method of Example 130, where the entity is a packet data network (PDN) gateway (PGW).

[0247] Example 135 is the method of Example 134, where the message is a create session request message from a serving gateway (SGW).

[0248] Example 136 is the method of Example 134, where the message is a modify bearer request message from a serving gateway (SGW).

[0249] Example 137 is the method of any one of Examples 130–136, where the information includes a packet switched (PS) data-off change status report.

[0250] Example 138 is an apparatus for the PCEF, the apparatus including manner for performing the method of any one of Examples 130-137.

[0251] Example 139. A computer-readable storage medium having instructions stored thereon that, when executed by a processor of the PCEF, cause the processor to perform the method of any one of Examples 130-137.

[0252] Example 140 is a server for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF). The server includes one or more network interfaces designed to receive a dynamic policy and charging control (PCC) rule from a policy and charging rules function (PCRF), and receive a packet switch (PS) data-off state of a user equipment (UE) from a core network entity. The server includes one or more network interfaces one or more baseband processors designed to allow transmission of packet flows that are related to the dynamic PCC rule when the PS data-off state is activated and the dynamic PCC rule indicates a service type as a PS data-off exempt service. The server includes one or more network interfaces one or more baseband processors designed to prevent transmission of

packet flows that are related to the dynamic PCC rule when the data-off state is activated and the dynamic PCC rule indicates a service type as a PS data-off non-exempt service or the dynamic PCC rule does not indicate a service type.

[0253] Example 141 is the server of Example 140, where the first network interface is designed to receive a plurality of dynamic PCC rules and where the one or more baseband processors are further designed to set a gate status of each dynamic PCC rule that indicates the PS data-off non-exempt service to closed when the data-off state is activated, and set a gate status of each dynamic PCC rule that indicates the PS data-off non-exempt service to open when the data-off state is deactivated.

[0254] Example 142 is the server of Example 141, where a gate status of each dynamic PCC rule that indicates the PS data-off exempt service is not changed when the data-off state is activated.

[0255] Example 143 is the server of any one of Examples 141–142, where the second network interface is designed to receive the PS data-off state of the UE from a serving gateway (SGW).

[0256] Example 144 is the server of any one of Examples 140–142, where the second network interface is designed to receive the PS data-off state of the UE from a serving general packet radio service (GPRS) support node (SGSN).

[0257] Example 145 is a method for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF). The method includes receiving a dynamic policy and charging control (PCC) rule from a policy and charging rules function (PCRF), and receiving a packet switch (PS) data-off state of a user equipment (UE) from a core network entity. The method includes allowing transmission of packet flows that are related to the dynamic PCC rule when the PS data-off state is activated and the dynamic PCC rule indicates a service type as a PS data-off exempt service, and preventing transmission of packet flows that are related to the dynamic PCC rule when the data-off state is activated and the dynamic PCC rule indicates a service type as a PS data-off non-exempt service or the dynamic PCC rule does not indicate a service type.

[0258] Example 146 is the method of Example 145, further includes setting a gate status of each dynamic PCC rule that indicates the PS data-off non-exempt service to

closed when the data-off state is activated, and setting a gate status of each dynamic PCC rule that indicates the PS data-off non-exempt service to open when the data-off state is deactivated.

[0259] Example 147 is the method of Example 146, where a gate status of each dynamic PCC rule that indicates the PS data-off exempt service is not changed when the data-off state is activated.

[0260] Example 148 is the method of any one of Examples 145–147, where the second network interface is designed to receive the PS data-off state of the UE from a serving gateway (SGW).

[0261] Example 149 is the method of any one of Examples 145–147, where the second network interface is designed to receive the PS data-off state of the UE from a serving general packet radio service (GPRS) support node (SGSN).

[0262] Example 150 is a computer-readable storage medium having instructions stored thereon that, when executed by a processor of the PGW, cause the processor to perform the method of any one of Examples 145–149.

[0263] Example 151 is an apparatus for the PGW, the apparatus including manner for performing the method of any one of Examples 145–149.

[0264] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, a non-transitory computer-readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a RAM, an EPROM, a flash drive, an optical drive, a magnetic hard drive, or another medium for storing electronic data. The eNodeB (or other base station) and UE (or other mobile station) may also include a transceiver component, a counter component, a processing component,

and/or a clock component or timer component. One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high-level procedural or an object-oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or an interpreted language, and combined with hardware implementations.

[0265] It should be understood that many of the functional units described in this specification may be implemented as one or more components, which is a term used to more particularly emphasize their implementation independence. For example, a component may be implemented as a hardware circuit comprising custom very large scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A component may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like.

[0266] Components may also be implemented in software for execution by various types of processors. An identified component of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, a procedure, or a function. Nevertheless, the executables of an identified component need not be physically located together, but may comprise disparate instructions stored in different locations that, when joined logically together, comprise the component and achieve the stated purpose for the component.

[0267] Indeed, a component of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within components, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as

electronic signals on a system or network. The components may be passive or activated, including agents operable to perform desired functions.

[0268] Reference throughout this specification to “an example” means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment. Thus, appearances of the phrase “in an example” in various places throughout this specification are not necessarily all referring to the same embodiment.

[0269] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on its presentation in a common group without indications to the contrary. In addition, various embodiments and examples may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of embodiments.

[0270] Although the foregoing has been described in some detail for purposes of clarity, it will be apparent that certain changes and modifications may be made without departing from the principles thereof. It should be noted that there are many alternative ways of implementing both the processes and apparatuses described herein. Accordingly, the present embodiments are to be considered illustrative and not restrictive, and the embodiments are not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

Claims

1. A server for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF) to control, based on a data-off function of a user equipment (UE), data charges calculated by data volume and attributable to wireless communications through an evolved universal mobile telecommunications service (UMTS) terrestrial radio access network (E-UTRAN), the server comprising:

a memory configured to store a message indicating a current state of the data-off function of the UE; and

processor circuitry configured to:

process the message to determine the current state of the data-off function of the UE, the data-off function having an activated state and a deactivated state;

set as closed a gate status of a policy and charging control (PCC) rule to suppress the data charges when the data-off function of the UE is in the activated state by causing downlink data traffic to be discarded; and

set as open the gate status of the PCC rule to allow the data charges when the data-off function of the UE is in the deactivated state by causing downlink data traffic to be transmitted.

2. The server of claim 1, wherein the processor circuitry is further configured to process PCC rules from a policy and charging rules function (PCRF) to determine whether a PCC rule is applicable to a service that incurs the data charges calculated by data volume.

3. The server of any one of claims 1 and 2, wherein the message is a first message and the processor circuitry is further configured to generate for a policy and charging rules function (PCRF) a second message including information corresponding to the current state of the data-off function of the UE.

4. The server of claim 1, wherein the processor circuitry is further configured to generate an acknowledgement message for a serving gateway (SGW) to acknowledge receipt of the message.

5. A computer-readable storage medium having instructions stored thereon that, when executed by a processor of a mobility management entity (MME), cause the processor to:

process a first message from a user equipment (UE) to identify a current state of a data-off function of the UE; and

generate, in response to identifying the current state of the data-off function of the UE, a second message for a serving gateway (SGW), the second message indicating the current state of the data-off function of the UE and causing a policy and charging enforcement function (PCEF) of a core network to change a charging configuration to, based on the current state of the data-off function of the UE, suppress or transmit data from services that incur data charges.

6. The computer-readable storage medium of claim 5, wherein the instructions further cause the processor to process an acknowledgement message from the SGW.

7. The computer-readable storage medium of claim 5, wherein the instructions further cause the processor to generate, in response to the first message, an acknowledgement message for the UE.

8. The computer-readable storage medium of any one of claims 5–7, wherein the instructions cause the processor to generate the second message as is one of a delete session request message, a create session request message, a bearer resource command message, or a delete session request message.

9. A computer-readable storage medium having instructions stored thereon that, when executed by a processor of a user equipment (UE), cause the processor to:

determine a current state of a data-off setting; and
generate for a mobility management entity (MME) a report including the current state of the data-off setting and thereby cause a policy and charging enforcement function (PCEF) of a core network to change a charging configuration between suppressions and transmission of data from services that incur volume-based data charges, the suppression and the transmission corresponding to, respectively, activated and deactivated states of the data-off setting.

10. The computer-readable medium of claim 9, wherein the instructions cause the processor to generate the report in a non-access stratum (NAS) message.

11. The computer-readable medium of claim 9, wherein the instructions cause the processor to generate the report in one of a session indication protocol (SIP) register message, an attach request message, a packet data network (PDN) connectivity request message, a request bearer resource modification message, or a tracking area update (TAU) message.

12. The computer-readable medium of claim 9, wherein the instructions cause the processor to process an acknowledgement message from the MME.

13. The computer-readable medium of claim 9, wherein the report comprises a packet switched (PS) data-off change status report generated in response to a change in the current state of the data-off setting of the UE.

14. The computer-readable medium of any one of claims 9–14, wherein the report is a first message and the wherein the instructions cause the processor to generate for a proxy call session control function (P-CSCF) a second message including the current state of the data-off setting of the UE.

15. A server for a serving gateway (SGW) that, based on a first message received from a mobility management entity (MME), reports to a packet data network

(PDN) gateway (PGW) of a core network a current state of a data-off function of a user equipment (UE) so as to suppress data charges attributable to wireless communications between the UE and the core network, the server comprising:

- a memory configured to store the first message, the first message indicating the current state of the data-off function of the UE; and

- processor circuitry configured to:

- process the first message to identify the current state of the data-off function of the UE; and

- in response to identifying a change of the data-off function , generate a second message indicating the current state the PGW and thereby cause a policy and charging enforcement function (PCEF) of the PGW to update, based on the current state, a charging configuration between suppression and transmission of data from services that incur the data charges.

16. The server of claim 15, wherein the processor circuitry is further configured to process an acknowledgement message from the PGW to confirm receipt of the second message by the PGW.

17. The server of claim 15, wherein the processor circuitry is further configured to generate an acknowledgement message for the MME.

18. The server of any one of claims 15–17, wherein the second message is a delete session request message.

19. The server of any one of claims 15–17, wherein the second message is a create session request message.

20. The server of any one of claims 15–17, wherein the second message is a bearer resource command message.

21. The server of any one of claims 15–17, wherein the second message is a modify bearer resource command message.

22. An apparatus for a server having a policy and charging rules function (PCRF) to facilitate control over data charges calculated by data volume and attributable to wireless communications between the UE and a core network, the server comprising:

a memory configured to store a message including information corresponding to a state of a data-off function of a user equipment (UE); and

processor circuitry configured to:

process the message to identify from the information the state of the data-off function of the UE;

generate, in response to identifying the state of the data-off function of the UE, a second message for a proxy call session control function (P-CSCF) including the information and thereby cause the P-CSCF to change, based on the state of the data-off function of the UE, a charging configuration between suppression and transmission of data from services that incur the data charges calculated by data volume; and

generate a policy and charging control (PCC) rule for a policy and charging enforcement function (PCEF) indicating whether a service incurs the data charges calculated by data volume.

23. The apparatus of claim 22, wherein the PCC rule provides for the service a dataflow descriptor that indicates whether the service incurs the data charges calculated by data volume.

24. The apparatus of claim 23, wherein the dataflow descriptor includes an internet protocol (IP) address of the P-CSCF to indicate whether the service incurs charges by data volume.

25. The apparatus of claim 23, wherein the dataflow descriptor includes an internet protocol (IP) address of a device management (DM) server, an extensible

markup language (XML) configuration access protocol (XCAP) server, or a domain name system (DNS) server.

26. The apparatus of claim 22, wherein the processor circuitry is further configured to generate the PCC rule to transmit over a Gx interface to a packet data network (PDN) gateway (PGW) .

27. The apparatus of any one of claims 22–26, wherein the processor circuitry is further configured to generate the PCC rule based on a transport address of a device management (DM) server or an extensible markup language (XML) configuration access protocol (XCAP) server.

28. A server for a packet data network (PDN) gateway (PGW) having a policy and charging and enforcement function (PCEF), the server comprising:

- one or more network interfaces configured to:

- receive a dynamic policy and charging control (PCC) rule from a policy and charging rules function (PCRF); and

- receive a packet switch (PS) data-off state of a user equipment (UE) from a core network entity; and

- one or more baseband processors configured to:

- allow transmission of packet flows that are related to the dynamic PCC rule when the PS data-off state is activated and the dynamic PCC rule indicates a service type as a PS data-off exempt service; and

- prevent transmission of packet flows that are related to the dynamic PCC rule when the data-off state is activated and the dynamic PCC rule indicates a service type as a PS data-off non-exempt service or the dynamic PCC rule does not indicate a service type.

29. The server of claim 28, wherein the first network interface is configured to receive a plurality of dynamic PCC rules and wherein the one or more baseband processors are further configured to:

set a gate status of each dynamic PCC rule that indicates the PS data-off non-exempt service to closed when the data-off state is activated; and

set a gate status of each dynamic PCC rule that indicates the PS data-off non-exempt service to open when the data-off state is deactivated.

30. The server of either of claims 29, wherein a gate status of each dynamic PCC rule that indicates the PS data-off exempt service is not changed when the data-off state is activated.

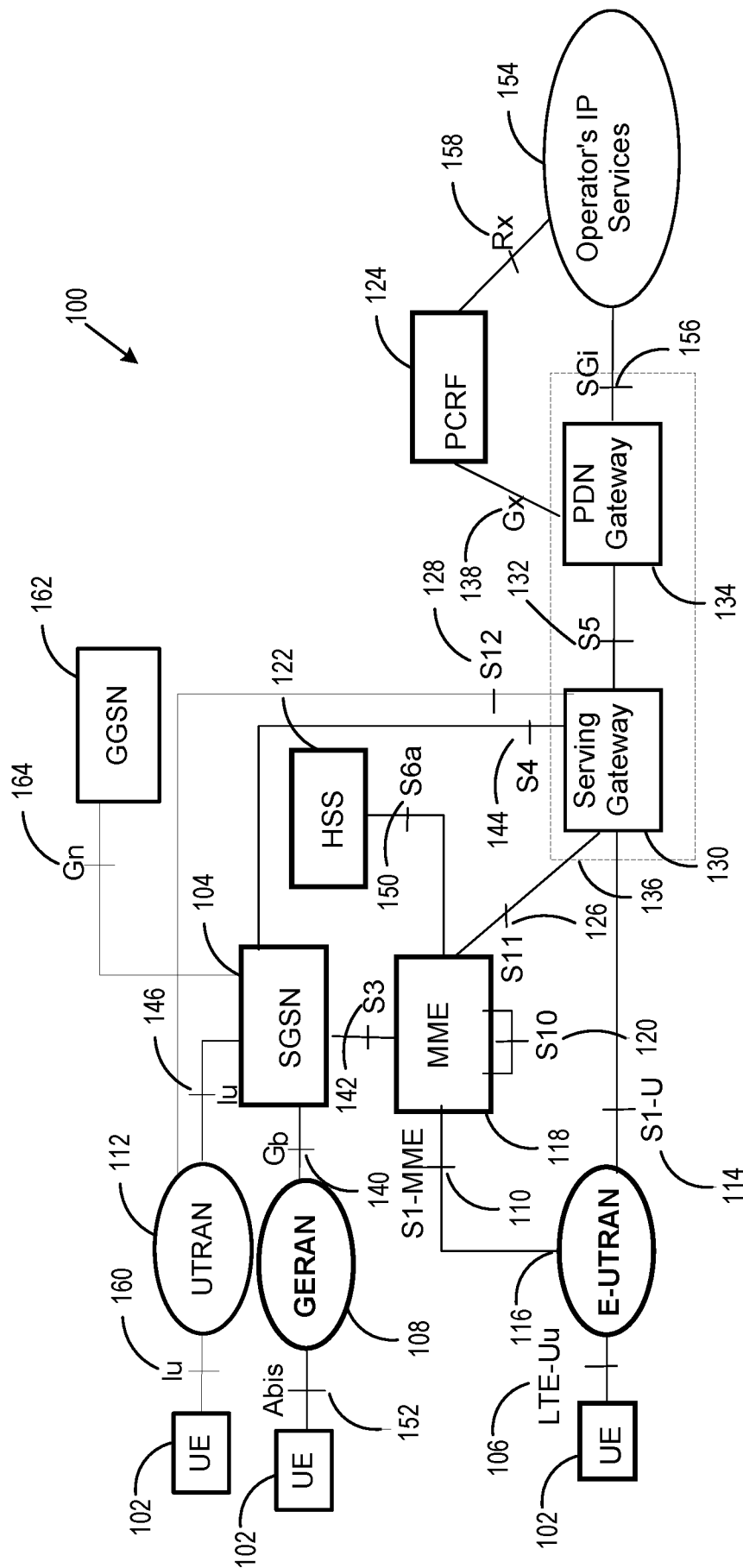


FIG. 1

200

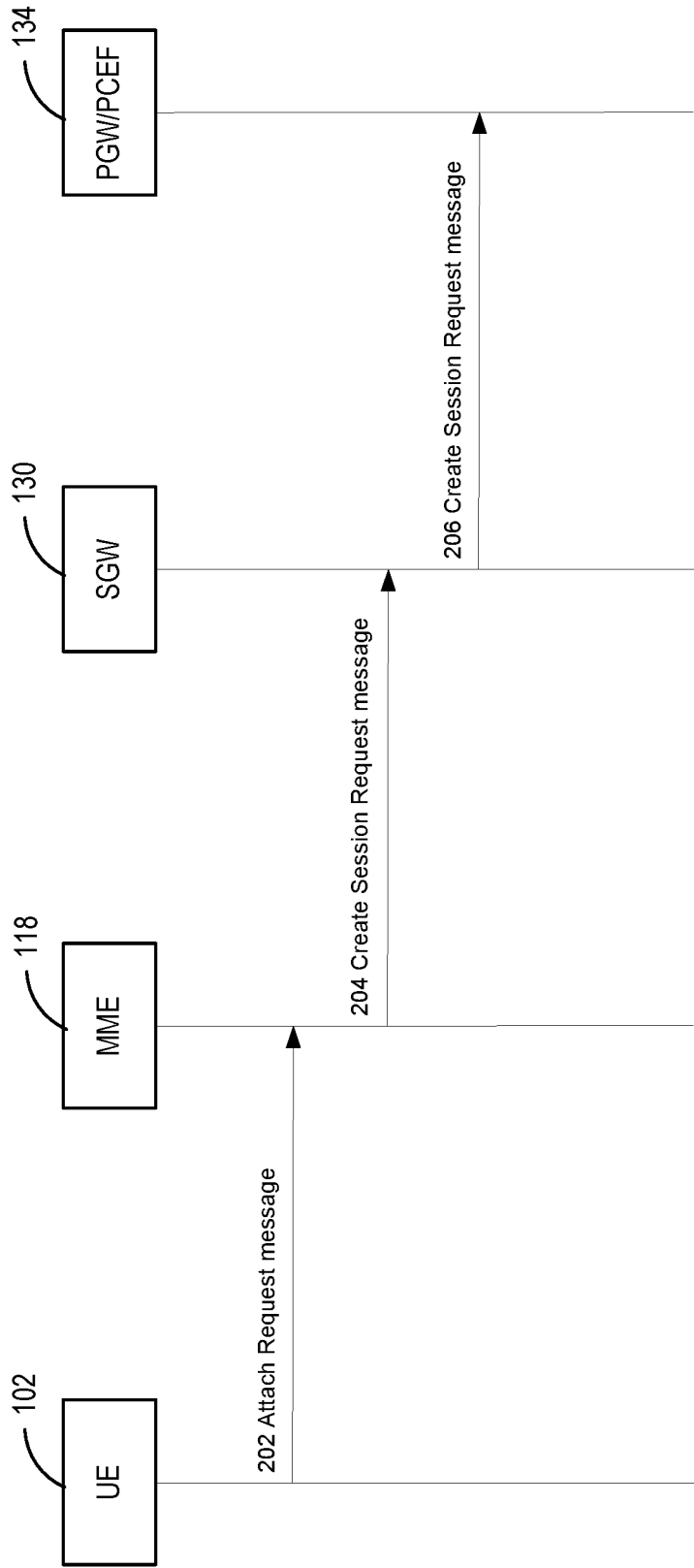


FIG. 2

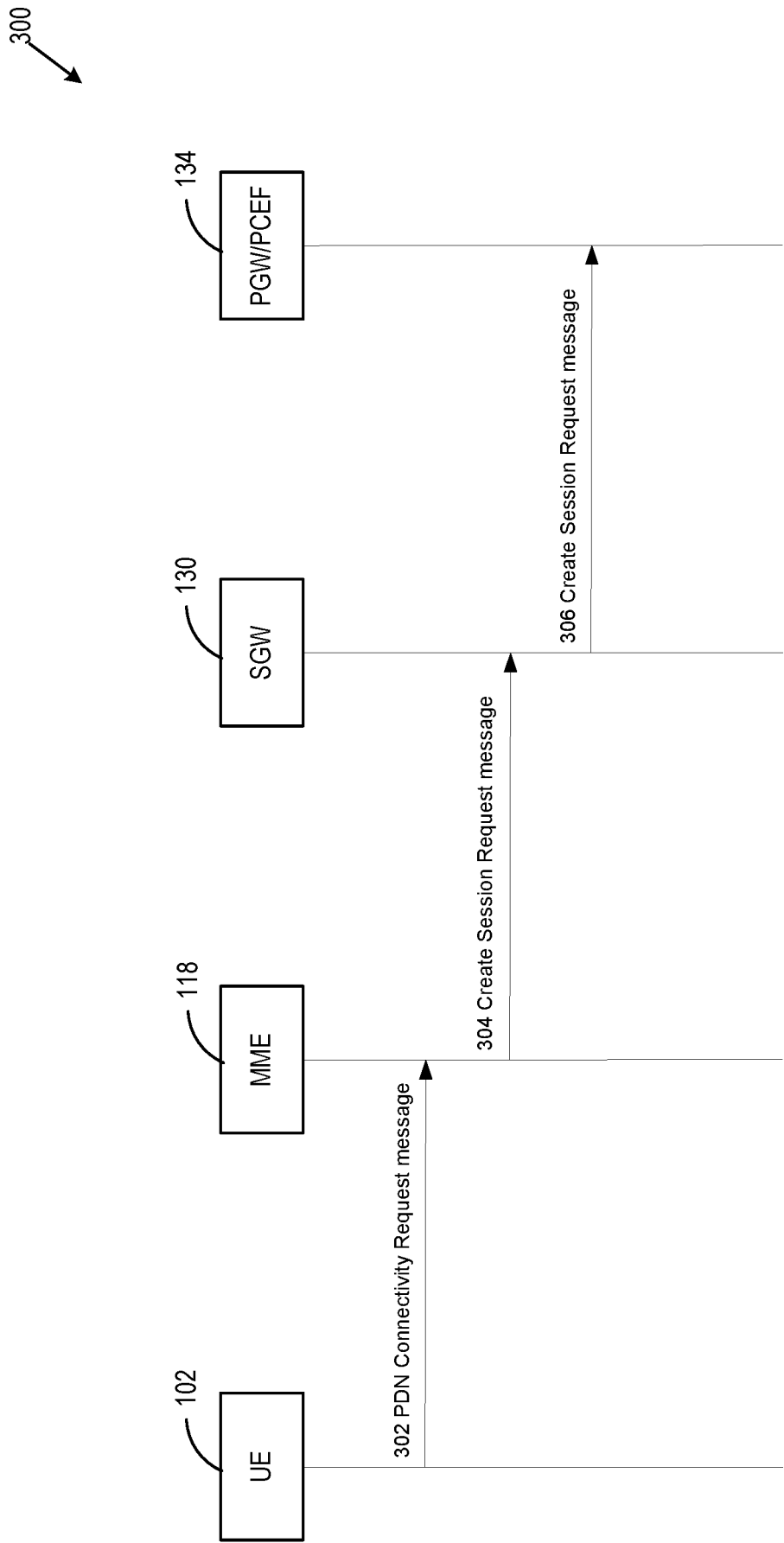


FIG. 3

400

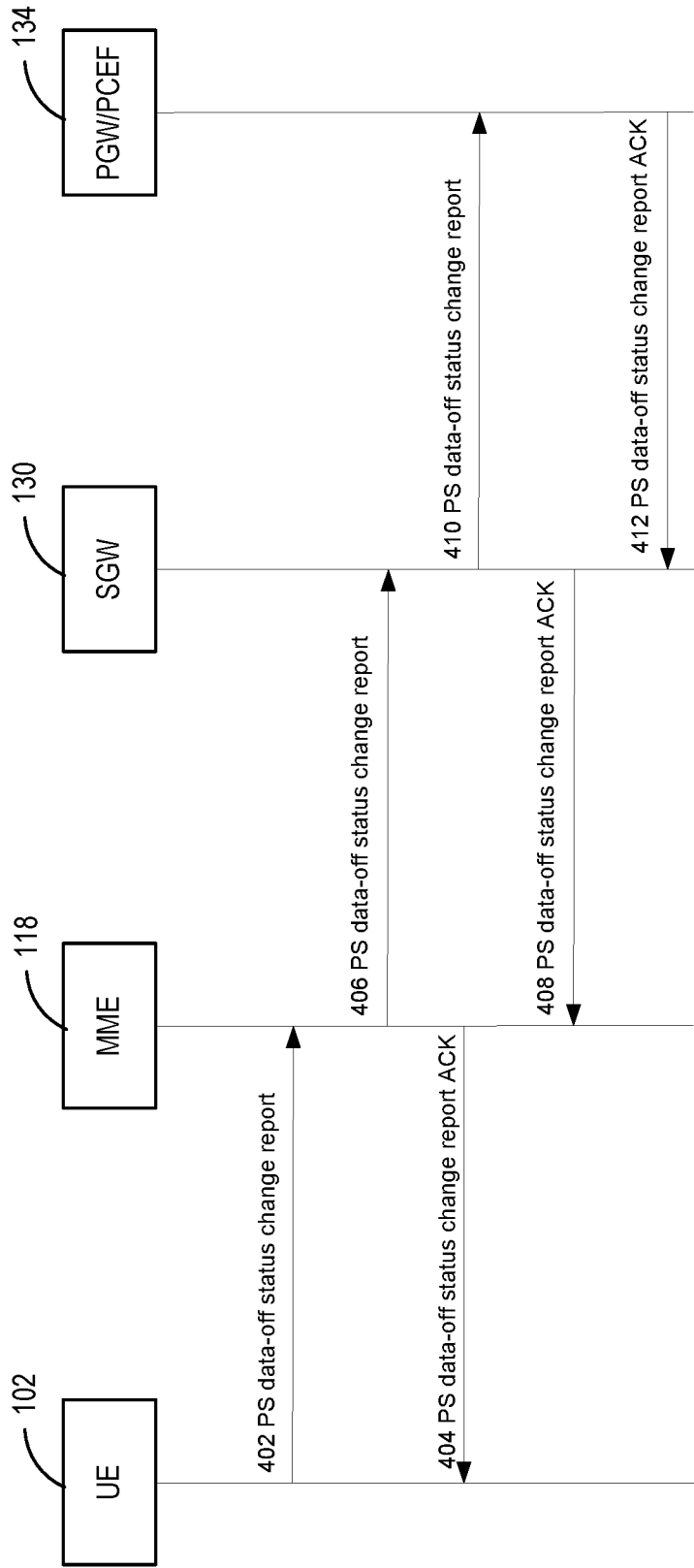


FIG. 4

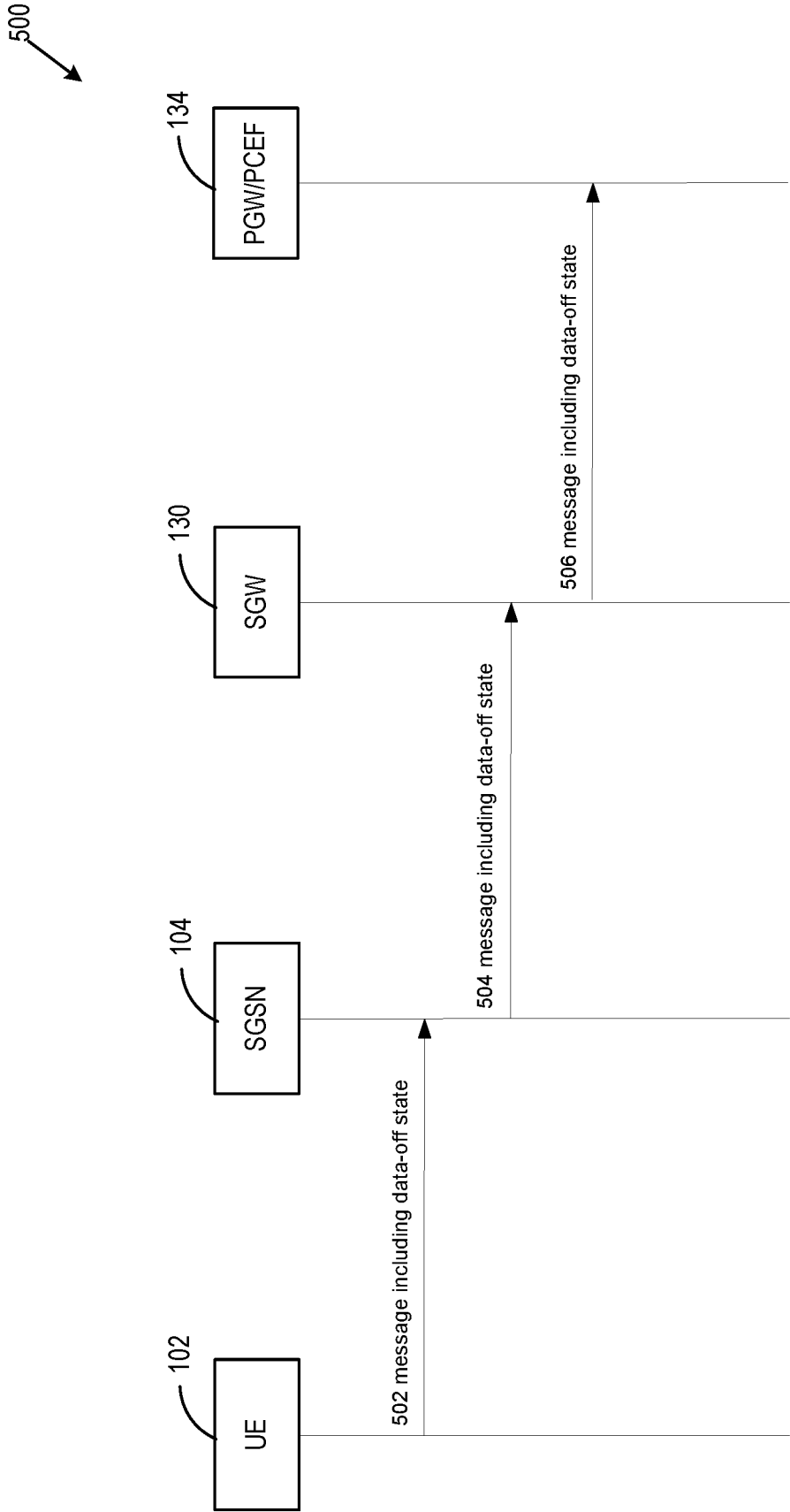


FIG. 5

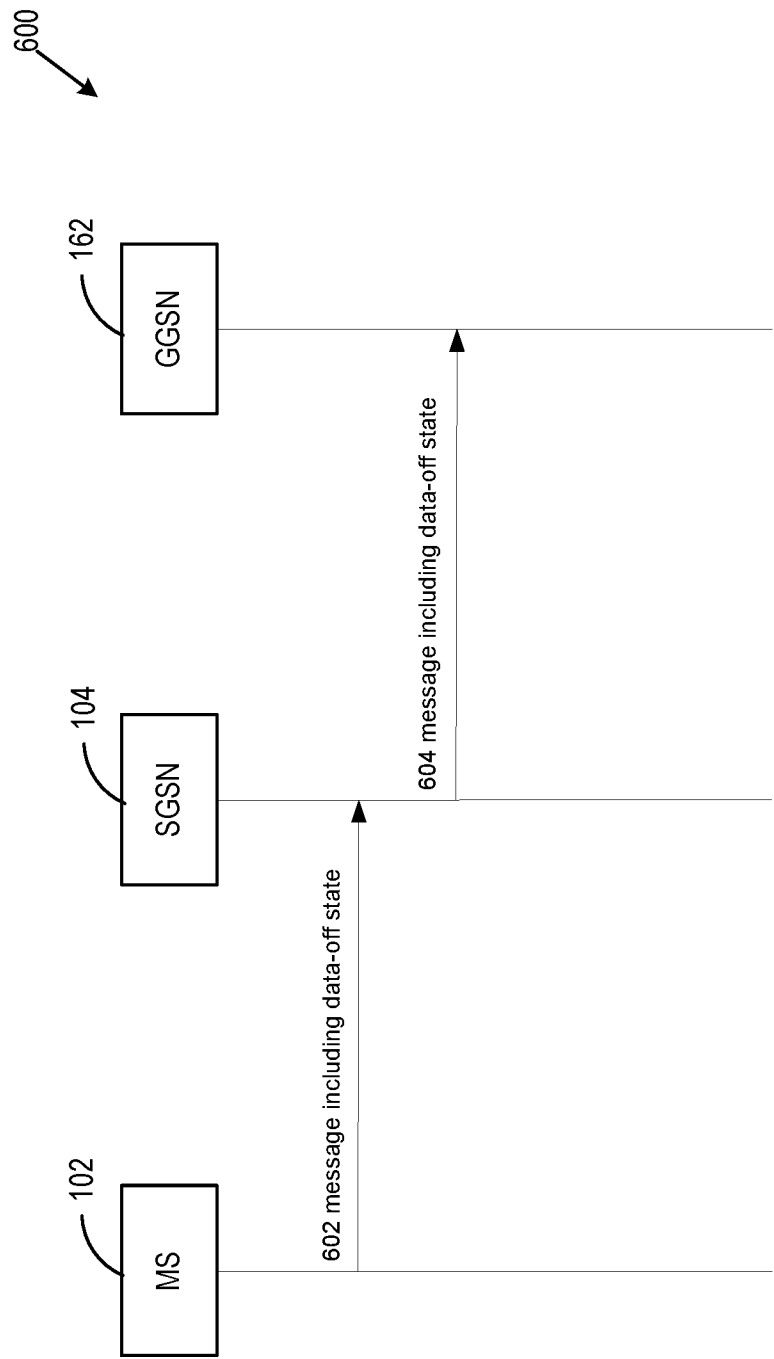


FIG. 6

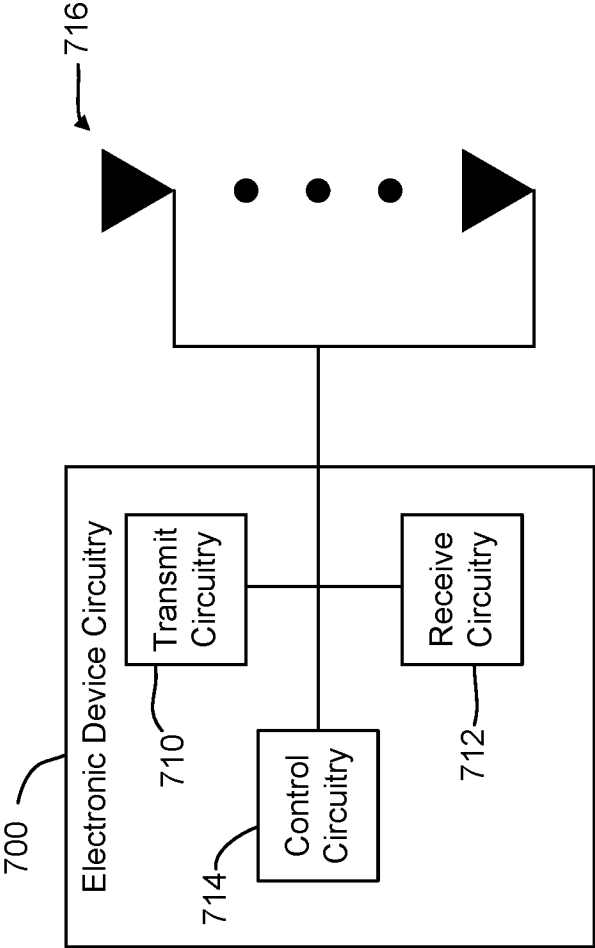


FIG. 7

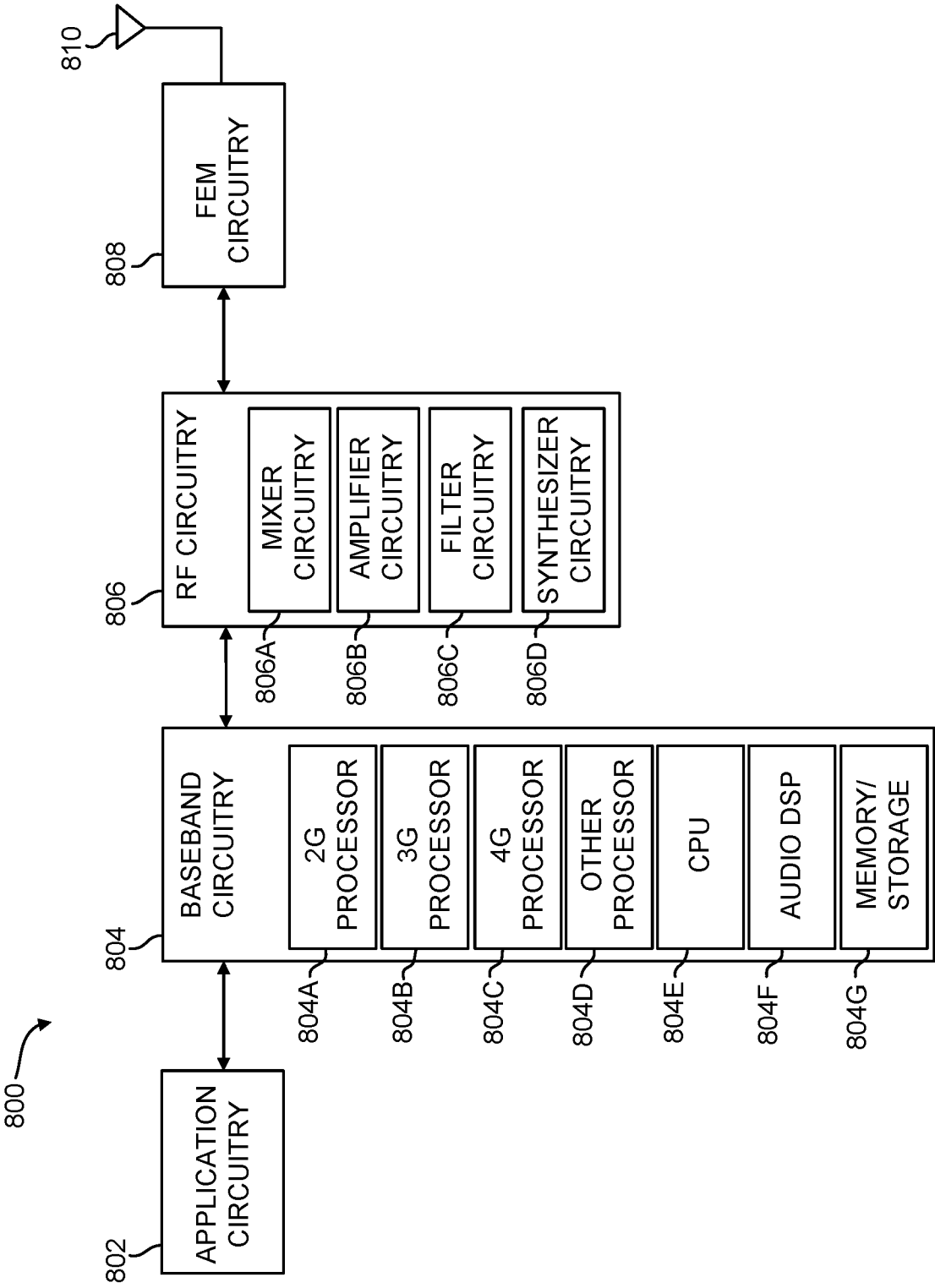
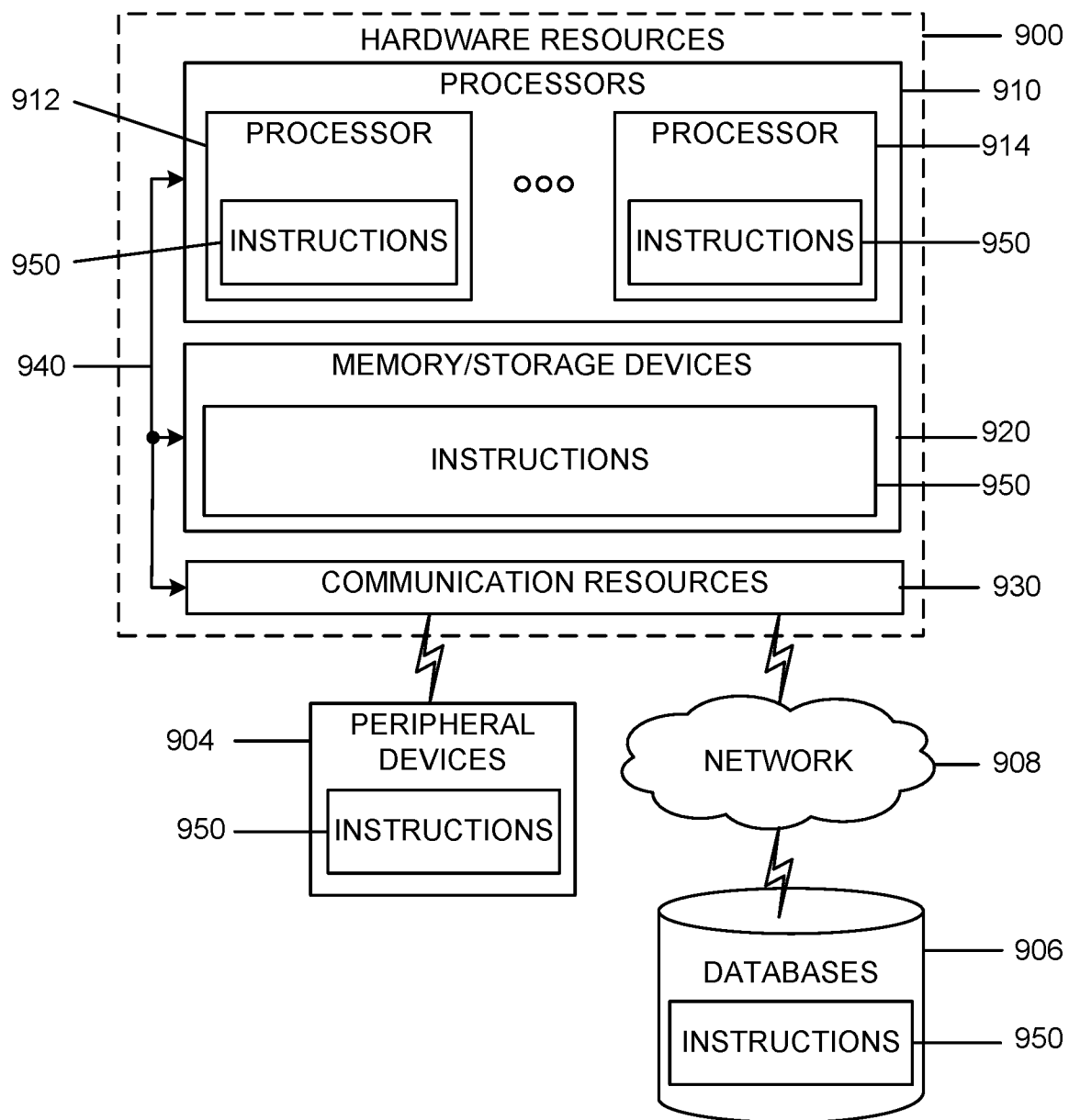


FIG. 8

**FIG. 9**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/027460

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L12/24 H04M15/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04M

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/129488 A1 (PATTERSON TAREN J [US] ET AL) 24 May 2012 (2012-05-24) abstract; figures 1, 3 paragraphs [0023] - [0025], [0039] - [0044] -----	1-30
A	WO 2015/158363 A1 (ERICSSON TELEFON AB L M [SE]) 22 October 2015 (2015-10-22) abstract; figure 1 page 1, lines 28-30 - page 13, lines 18-24 -----	1-30
A	WO 2014/194936 A1 (ERICSSON TELEFON AB L M [SE]) 11 December 2014 (2014-12-11) abstract; figures 5, 21 page 6, line 31 - page 7, line 15 -----	1-30



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

25 July 2017

Date of mailing of the international search report

02/08/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Fantacone, Vincenzo

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/027460

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012129488	A1	24-05-2012	NONE

WO 2015158363	A1	22-10-2015	CN 106464568 A 22-02-2017
			EP 3132575 A1 22-02-2017
			US 2016261754 A1 08-09-2016
			WO 2015158363 A1 22-10-2015

WO 2014194936	A1	11-12-2014	US 2016128133 A1 05-05-2016
			WO 2014194936 A1 11-12-2014
