



(51) International Patent Classification:
H04W 36/12 (2009.01) *H04W 8/08* (2009.01)

(21) International Application Number:
PCT/US2017/020737

(22) International Filing Date:
03 March 2017 (03.03.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PCT/CN2016/094859
12 August 2016 (12.08.2016) CN

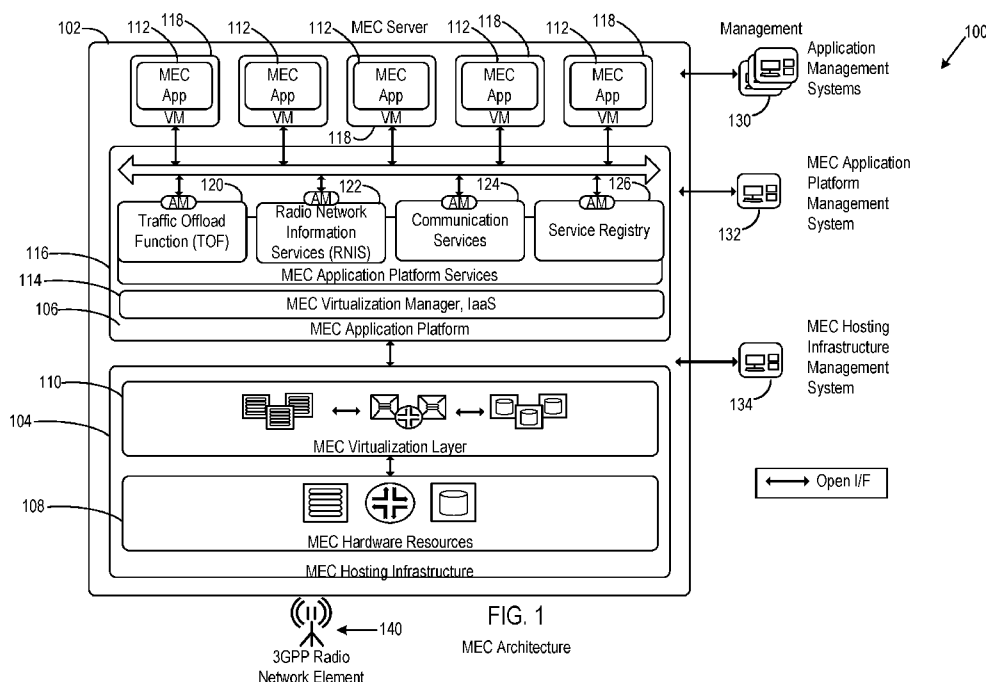
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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, 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,

(54) Title: SYSTEMS, METHODS AND DEVICES FOR MOBILE EDGE COMPUTING - RADIO ACCESS NODE CONTROL PLANE INTERFACE



(57) Abstract: A control plane interface is established between a mobile edge computing (MEC) server and a RAN node that provides radio network information (RNI). The control plane interface can be used by the MEC server to receive one time or periodic reports on RNI. The MEC server can use the RNI in different ways, including (1) providing some or all of the RNI to a third-party application hosted in the MEC; (2) performing traffic analysis with the information and providing statistics on whether any specific application is used in this region exceeding a threshold to enable a local network to be updated with specific application server support and/or network congestion support; or (3) using a rate policing mechanism in the MEC server for traffic for which the MEC server is the end point) and performing filtering if more than a specific number of flows or UEs are served through the MEC.

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.

(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))*

SYSTEMS, METHODS AND DEVICES FOR MOBILE EDGE COMPUTING - RADIO ACCESS NODE CONTROL PLANE INTERFACE

Related Application

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of PCT Application No. PCT/CN2016/094859 filed August 12, 2016, which is incorporated by reference herein in its entirety.

Technical Field

[0002] The present disclosure relates to mobile edge computing (MEC) and more specifically to a control plane interface between a RAN node and a MEC server.

Background

[0003] Wireless mobile communication technology uses various standards and protocols to transmit data between a base station and a wireless mobile device. Wireless communication system standards and protocols can include the 3rd Generation Partnership Project (3GPP) long term evolution (LTE); the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard, which is commonly known to industry groups as worldwide interoperability for microwave access (WiMAX); and the IEEE 802.11 standard for wireless local area networks (WLAN), which is commonly known to industry groups as Wi-Fi. In 3GPP radio access networks (RANs) in LTE systems, the base station can include a RAN node such as a Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (also commonly denoted as evolved Node B, enhanced Node B, eNodeB, or eNB) and/or Radio Network Controller (RNC) in an E-UTRAN, which communicate with a wireless communication device, known as user equipment (UE). In fifth generation (5G) wireless RANs, RAN nodes can include a 5G Node or gNB.

[0004] RANs use a radio access technology (RAT) to communicate between the RAN node and UE. RANs can include global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE) RAN (GERAN), Universal Terrestrial Radio Access Network (UTRAN), and/or E-UTRAN, which provide access to communication services through a core network. Each of the RANs operates according to a specific 3GPP RAT. For

example, the GERAN implements GSM and/or EDGE RAT, the UTRAN implements universal mobile telecommunication system (UMTS) RAT or other 3GPP RAT, and the E-UTRAN implements LTE RAT.

[0005] A core network can be connected to the UE through the RAN node. The core network can include a serving gateway (SGW), a packet data network (PDN) gateway (PGW), an access network detection and selection function (ANDSF) server, an enhanced packet data gateway (ePDG) and/or a mobility management entity (MME).

Brief Description of the Drawings

[0006] FIG. 1 is a diagram illustrating a MEC server consistent with embodiments disclosed herein.

[0007] FIG. 2 is a diagram illustrating mobile edge computing with a MEC control interface to a RAN node consistent with embodiments disclosed herein.

[0008] FIG. 3 is a table of definitions for a radio network information (RNI) report consistent with embodiments disclosed herein.

[0009] FIG. 4 is a diagram illustrating a radio access network (RAN) system consistent with embodiments disclosed herein.

[0010] FIG. 5 is a diagram illustrating electronic device circuitry that can be RAN node circuitry, user equipment circuitry, or network node circuitry consistent with embodiments disclosed herein.

[0011] FIG. 6 is a diagram illustrating example components of a user equipment (UE) or mobile station (MS) device consistent with embodiments disclosed herein.

[0012] FIG. 7 is a flow chart illustrating a method for performing operations of a mobile edge computing (MEC) node consistent with embodiments disclosed herein.

[0013] FIG. 8 is a block diagram illustrating components able to read instructions from a machine-readable or computer-readable medium consistent with embodiments disclosed herein.

Detailed Description

[0014] A detailed description of systems and methods consistent with embodiments of the present disclosure is provided below. While several embodiments are described, it should be understood that the disclosure is not limited to any one embodiment, but instead encompasses numerous alternatives, modifications, and equivalents. In addition, while numerous specific details are set forth in the following description in order to provide a thorough understanding of the embodiments disclosed herein, some embodiments can be practiced without some or all of these details. Moreover, for the purpose of clarity, certain technical material that is

known in the related art has not been described in detail in order to avoid unnecessarily obscuring the disclosure.

[0015] Techniques, apparatus and methods are disclosed that enable a control plane interface between a mobile edge computing (MEC) server and a RAN node that provides radio network information (RNI). The control plane interface can be used by the MEC server to receive one time or periodic reports on RNI. The MEC server can use the RNI in different ways, including (1) providing some or all of the RNI to a third-party application hosted in the MEC (e.g., with or near the MEC server); (2) performing traffic analysis with the information and providing statistics on whether any specific application is used in this region exceeding a threshold (e.g., more than others, a fixed threshold, etc.) to enable a local network to be updated with specific application server support and/or network congestion support; or (3) using a rate policing mechanism in the MEC server (e.g., similar to the aggregate maximum bit rate (AMBR) for traffic for which the MEC server is the end point) and performing filtering if more than a specific number of flows or UEs are served through the MEC.

[0016] In addition to offload capabilities, MEC also can use certain radio related information for the Radio Network Information (RNI) service API. This information can be used by MEC servers, e.g., to make offloading decisions. This interface is defined within this disclosure.

[0017] A control plane interface between MEC and RAN (i.e., (fifth generation/new radio (5G/NR) base station) is defined through which MEC may retrieve the radio related information related to radio conditions, such as: physical resource block (PRB) usage (e.g., Total PRB usage and per traffic class); number of active UEs per quality of service class indicator (QCI) in downlink (DL) or in uplink (UL); packet delay in the DL per QCI; data Loss (e.g., packet discard rate in the DL per QCI, packet Uu Loss Rate in the DL and in UL per QCI); scheduled IP throughput (e.g., in DL and/or in UL), minimization of drive test (MDT) measurements; data volume (in DL and/or in UL); or E-UTRAN measurements performed by the UE (e.g., Packet Delay). The metrics listed above are examples. The control plane interface between a RAN node (e.g., NR eNB, etc.) and MEC defined in the present disclosure can support other information as well.

[0018] The above information can be used by MEC, e.g., for offload decisions. For example, the RNI can be used to decide which bearers/IP flows should be offloaded to MEC. Other optimizations decisions are also possible and described below.

[0019] UE identity can also be used in communications between RAN and MEC.

[0020] Mobile Edge Computing (MEC) is a technology that provides an IT service environment and cloud-computing capabilities at the edge of the mobile network (e.g., in

close proximity to mobile subscribers). The MEC can be used to reduce latency, ensure highly efficient network operation and/or service delivery, and/or offer an improved user experience. MEC is also being considered as a 5G technology to address end-to-end low latency.

[0021] Mobile-Edge Computing (MEC) can provide application developers and content providers cloud-computing capabilities and an IT service environment at an edge of a mobile network. This environment can enable ultra-low latency and/or high bandwidth as well as real-time access to radio network information that can be leveraged by applications.

[0022] FIG. 1 is a diagram illustrating a MEC server. A Traffic Offload Function (TOF) in MEC can route selected, policy-based, user-data stream to and from authorized applications. As shown in FIG. 1, TOF can be built as the component in a MEC server which is deployed either at a RAN node (e.g., HeNB, gNB or eNB) site, or at a 3G Radio Network Controller (RNC) site, or at a multi-technology (3G/LTE) cell aggregation site.

[0023] The MEC server 102 forms part of Mobile Edge Computing. It includes a hosting infrastructure 104 and an application platform 106. The hosting infrastructure 104 includes hardware resources 108 and a virtualization layer 110. The application platform 106 provides the capabilities for hosting applications 112 and consists of the application's virtualization manager 114 enabling the Infrastructure as a Service (IaaS) facilities and application platform services 116 enabling the Platform as a Service (PaaS) facilities with provision of a set of middleware services (e.g., TOF 120, radio network information services (RNIS) 122, communication services 124, and/or service registry 126) to the hosted applications 112. The hosted applications 112 are delivered as packaged-operating system Virtual Machine (VM) images 118. Management systems 130, 132, 134 can provide management functionality at various granularities, including application management systems 130 for MEC applications 112, application platform management systems 132 for the MEC application platform 106 and hosting infrastructure management systems 134 for the MEC hosting infrastructure 104. The MEC server 102 can communicate with RAN nodes, such as 3GPP radio network elements 140.

[0024] TOF in MEC can be supplied to applications in the following two ways: a pass-through mode where (uplink and/or downlink) user plane traffic is passed to an application which can monitor, modify or shape it and then send it back to the original PDN connection; or an end-point mode where the traffic is terminated by the application which acts as a server. In one embodiment, filters at the E-UTRAN Radio Access Bearer (E-RAB) or the packet levels are set as given within a traffic offloading policy. E-RAB policy filters can be the

basis of Subscriber Profile ID (SPID), Quality Class Indicator (QCI) and Allocation Retention Priority (ARP). The packet filters can be based on the 3-tuple (UE IP address, network IP address and IP protocol). Additional filtering criteria can also be supported.

[0025] FIG. 2 is a diagram illustrating mobile edge computing 200 with a MEC control interface 206 to a RAN node 204. A MEC 202 (which can include one more servers) exists on a user plane interface (NG3) 212 between the RAN node 204 and the core network 216. The RAN node can have a control plane interface (NG2) to the core network 216. The MEC 202 can include a local network interface (NG6) 214 which can provide traffic offloading and/or third-party services using a local network 208.

[0026] One of the ways to implement MEC 202 in RAN (5G/NR or LTE) is to place the MEC 202 on the user plane interface 212 between one or more RAN nodes 204 and the core network 216 (e.g., on NG3), so that the MEC function itself will be able to decide which traffic to intercept or offload. The control plane interface between MEC and RAN is described herein and denoted NGx in the FIGs. Note that different MEC placement options can be used, however, for simplifying the description; the placement shown in FIG. 2 can be used. Regardless of a placement option selected, the MEC can use a control plane interface 206.

[0027] The MEC-RAN control plane interface (NGx) can provide information about the RAN node to support MEC. It should be noted that LTE terminology is used below for clarity of description, but it is understood that once equivalent 5G/NR terminology is defined, it can also be applicable to the interface defined herein.

[0028] Radio network interface (RNI) information collection can be performed by the RAN node and queried by the MEC through the NGx interface. For example, the MEC can request an eNB to report (once or periodically) certain information. In one embodiment, the information is classified as: per eNB, per cell, per UE, per QCI, per bearer and/or related to congestion. A per eNB classification can include backhaul capacity and load, congestion indicator, etc. A per cell classification can include total PRB usage (or its equivalent in 5G/NR), number of active UEs, congestion indicator, etc. A per UE classification can include scheduled IP throughput, etc. A per QCI (or other equivalent parameter in 5G/NR) can include PRB usage per QCI, number of active UEs per QCI, etc. A per bearer (or per IP flow, if 5G/NR uses IP flows instead of bearers) can include data volume, etc. A congestion indicator can be derived by MEC or explicitly sent. It should be noted that parameters can be reported separately for uplink or downlink. The parameters listed above are just examples – and the NGx interface is expected to support different kinds of radio related information.

[0029] The MEC can request reporting of the above parameters. In one embodiment, the MEC uses a NGx RESOURCE STATUS REQUEST message, indicating which parameters it is interested in and whether these should be reported in one shot or periodically. If the eNB acknowledges the request, e.g., using NGx RESOURCE STATUS RESPONSE, it performs the measurements and reports these to MEC using a NGx RESOURCE STATUS UPDATE message.

[0030] The MEC can use RNI in several different ways, including (1) providing some or all of the RNI to a third-party application hosted in the MEC (e.g., with or near the MEC server); (2) performing traffic analysis with the information and provide statistics on whether any specific application is used in this region exceeding a threshold (e.g., more than others, a fixed threshold, etc.) to enable the local network to be updated with specific application server support and/or network congestion support; or (3) using a rate policing mechanism in the MEC server (e.g., similar to the aggregate maximum bit rate (AMBR) for traffic for which the MEC server is the end point) and performing filtering if more than a specific number of flows or UEs are served through the MEC.

[0031] For example, in option 1, RNI information is passed to third-party applications hosted in the MEC. The RNI reported by the eNB is shared with a hosted application. For example, the third-party application initiates a corresponding representational state transfer (RESTful) API in which HTTP requests to retrieve the RNI data are issued from a third-party application to the MEC application platform service. The RNI data is then provided to the third-party application with the HTTP response.

[0032] For example, in option 2, the MEC server (which can be co-located with third-party applications) can do traffic analysis with the RNI information. The MEC server can also provide statistics on whether any specific application is used in this region a lot more than other applications. These statistics can be used to enable the local network to be updated with specific application server support for the specific application. It can thus provide localized modeling. These statistics can be provided using new messages or APIs such as NGx ASSISTANCE INFORMATION or a generic terminology with information elements (IEs) including the port/application ID if known/http request information identifying the application, etc. This RNI information can also help to identify opportunities for a proactive caching technique for an edge content delivery application.

[0033] When congestion information is sent by the eNB, a MEC server can perform content scaling to save on resources (e.g., downscaling the content). In another example, the MEC server can identify opportunities for local content delivery. Messages or information during a

local event can be quickly delivered in downlink. For enterprise applications, it can be useful to control congestion, as the message need not travel through the core network. Furthermore, if a measured cell load is above a certain level, the MEC server can apply certain policies per UE per application.

[0034] For example, in option 3, a rate policing mechanism is introduced in the MEC server for traffic for which the MEC server is the end point (in one embodiment, it can be similar to the Aggregate Maximum Bit Rate (AMBR)). The 5-tuple values (e.g., Source IP address, Destination IP address, Source port number, Destination port number, Protocol ID) can be used to perform some form of filtering if more than a specific number of flows or UEs are served through MEC.

[0035] In one embodiment, two options can be used upon exceeding the limit at the server to handle IP packets: (1) the MEC server may trigger offloading (e.g., if traffic is above threshold) or transparently forward the traffic to the core network (e.g., if traffic is below threshold) or (2) the MEC server may drop those IP packets. These actions can be conditionally triggered if a congestion/overload indication is received from the eNB. A UL scheduling algorithm at the eNB can take care of sending packets in order to the MEC server which treats the packets in the FIFO model.

[0036] The MEC server can keep track of the IP 5-tuple of the packets that are sent in uplink through an endpoint. When downlink packets arrive in this path, at least some of the packets most likely correspond to the uplink flow that was previously sent. This correspondence can provide an opportunity for scheduling quality of service (QoS) modeling, which can have advantages under a congestion scenario. For example, the eNB can determine whether the packets arrived via the local network or from the core network.

[0037] When a MEC server determines that it can serve a specific UE by doing a lookup in a table of supported services (e.g., using the 5-tuple), the MEC server can inform the eNB using a specific message (e.g., NGx SESSION SUPPORTED with the UE ID within). The eNB can mark the corresponding data radio bearer (DRB) ID of the UE as being served through the local network. In some embodiments, the system adjusts its evolved packet system (EPS) bearer QoS enforcement rules accordingly.

[0038] In some embodiments, the UE identity is also used. For example, the IP address of the UE can be used as a UE identity for RNI reporting in the MEC. A third-party application hosted in MEC can extract the identity from a packet coming from the UE through the user plane. The MEC may use an interface to other core network nodes (e.g., MME) if this identity is to be mapped to the UE identity used in RAN.

[0039] In some embodiments, a packet filter is based on the 5-tuple (UE IP address, network IP address, UE port number, network port number and IP protocol). The 5-tuple is used as the identity in MEC requested RNI report per bearer. The eNB creates a mapping between the packet filter and bearer identity upon delivering the message over the NG3 interface for the bearer establishment. Thus, eNB is able to report the corresponding RNI after receiving the RNI request identified with the packet filter.

[0040] FIG. 3 is a table of definitions for a radio network information (RNI) report. In some embodiments, a new set of application identifiers, command codes and Attribute-Value-Pairs (AVP) are introduced for the RNI report as listed in the table 300 in FIG. 3. A content of the RNI data is encoded as the key-value element such as {information_name: value}. Given the command for the RNI request, content of the RNI data is encoded as {information_name: }. Multiple key-value elements are allowed to be contained in the single AVP.

[0041] In some embodiments, a control interface (NGx) establishment between the MEC and RAN node can follow a Diameter-based protocol. For example, the MEC acts as a Diameter client to initiate a Diameter session with an eNB that takes the role of a Diameter server. After the accomplishment of the Diameter session establishment, the MEC issues a Diameter message asking for an RNI report and the eNB then responds with a Diameter message containing the requested RNI.

[0042] In another embodiment, the NGx interface is modelled after an X2 interface and can support an Application Protocol (NGx-AP) to convey control plane information, modelled after X2-AP. The interface can thus support message exchange such as NGx-AP SETUP REQUEST, NGx-AP SETUP RESPONSE or NGx-AP SETUP FAILURE. The setup procedure can be initiated either by MEC or by the eNB. In some embodiments, establishment can use a certain amount of operation and management (OAM) information (e.g., eNB and MEC IP addresses).

[0043] FIG. 4 is an example of a portion of a radio access network (RAN) system 400 that includes a cellular air interface (such as an LTE/LTE-Advanced access link) being provided between RAN node A 404 and the UE 402 (i.e., on Access Link A), and a second air interface (such as a second cellular access interface, a supplemental network interface such as a wireless local area network (WLAN) based interface, etc.) being provided between the RAN node B 406 and the UE 402 (i.e., on Access Link B). UE 402 is located within macro cell coverage 408. The UE 402 determines that connection with a RAN node B 406 will be beneficial to a user of the UE 402. In some embodiments, the UE 402 retains Access Link A to RAN node B 406. The UE 402 can offload some or part of wireless services onto Access

Link A. In other embodiments, the UE 402 disconnects from Access Link A and moves wireless services to Access Link B. In some embodiments Access Link A and Access Link B use a same frequency and technology. In other embodiments, Access Link A and Access Link B use different frequencies (e.g., LTE licensed frequencies and unlicensed frequencies) and different link technology (e.g., LTE and Wi-Fi). In other embodiments, Access Link A and Access Link B use different frequencies and the similar link technology (e.g., LTE and LTE over mmWave).

[0044] FIG. 5 is a block diagram illustrating electronic device circuitry 500 that may be radio access node (RAN) node circuitry (such as an eNB circuitry), UE circuitry, network node circuitry, or some other type of circuitry in accordance with various embodiments. In embodiments, the electronic device circuitry 500 may be, or may be incorporated into or otherwise a part of, a RAN node (e.g., an eNB), a UE, a mobile station (MS), a BTS, a network node, or some other type of electronic device. In embodiments, the electronic device circuitry 500 may include radio transmit circuitry 510 and receive circuitry 512 coupled to control circuitry 514 (e.g., baseband processor(s), etc.). In embodiments, the transmit circuitry 510 and/or receive circuitry 512 may be elements or modules of transceiver circuitry, as shown. In some embodiments, some or all of the control circuitry 515 can be in a device separate or external from the transmit circuitry 510 and the receive circuitry 512 (baseband processors shared by multiple antenna devices, as in cloud-RAN (C-RAN) implementations, for example).

[0045] The electronic device circuitry 510 may be coupled with one or more plurality of antenna elements 516 of one or more antennas. The electronic device circuitry 500 and/or the components of the electronic device circuitry 500 may be configured to perform operations similar to those described elsewhere in this disclosure.

[0046] In embodiments where the electronic device circuitry 500 is or is incorporated into or otherwise part of a UE, the transmit circuitry 510 can transmit data and/or RNI information as shown in FIG. 4. The receive circuitry 512 can receive data as shown in FIG. 4.

[0047] In embodiments where the electronic device circuitry 500 is an eNB, BTS and/or a network node, or is incorporated into or is otherwise part of an eNB, BTS and/or a network node, the transmit circuitry 510 can transmit reports or establish a control plane interface as shown in FIG. 2. The receive circuitry 512 can receive requests for reports and establish a control plane interface as shown in FIG. 2.

[0048] In certain embodiments, the electronic device circuitry 500 shown in FIG. 5 is operable to perform one or more methods, such as the methods shown in FIG. 7.

[0049] 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.

[0050] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 6 is a block diagram illustrating, for one embodiment, example components of a user equipment (UE) or mobile station (MS) device 600. In some embodiments, the UE device 600 may include application circuitry 602, baseband circuitry 604, Radio Frequency (RF) circuitry 606, front-end module (FEM) circuitry 608, and one or more antennas 610, coupled together at least as shown in FIG. 6.

[0051] The application circuitry 602 may include one or more application processors. By way of non-limiting example, the application circuitry 602 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.

[0052] By way of non-limiting example, the baseband circuitry 604 may include one or more single-core or multi-core processors. The baseband circuitry 604 may include one or more baseband processors and/or control logic. The baseband circuitry 604 may be configured to process baseband signals received from a receive signal path of the RF circuitry 606. The baseband 604 may also be configured to generate baseband signals for a transmit signal path of the RF circuitry 606. The baseband processing circuitry 604 may interface with the application circuitry 602 for generation and processing of the baseband signals, and for controlling operations of the RF circuitry 606.

[0053] By way of non-limiting example, the baseband circuitry 604 may include at least one of a second generation (2G) baseband processor 604A, a third generation (3G) baseband processor 604B, a fourth generation (4G) baseband processor 604C, other baseband processor(s) 604D 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 604

(e.g., at least one of baseband processors 604A-604D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 606. 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 604 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 604 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.

[0054] In some embodiments, the baseband circuitry 604 may include elements of a protocol stack. By way of non-limiting example, elements of an evolved universal terrestrial radio access network (EUTRAN) 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) 604E of the baseband circuitry 604 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 604 may include one or more audio digital signal processor(s) (DSP) 604F. The audio DSP(s) 604F may include elements for compression/decompression and echo cancellation. The audio DSP(s) 604F may also include other suitable processing elements.

[0055] The baseband circuitry 604 may further include memory/storage 604G. The memory/storage 604G may include data and/or instructions for operations performed by the processors of the baseband circuitry 604 stored thereon. In some embodiments, the memory/storage 604G may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 604G 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 604G may be shared among the various processors or dedicated to particular processors.

[0056] Components of the baseband circuitry 604 may be suitably combined in a single chip, 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 604 and the application circuitry 602 may be implemented together, such as, for example, on a system on a chip (SOC).

[0057] In some embodiments, the baseband circuitry 604 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 604 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 604 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0058] The RF circuitry 606 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 606 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. The RF circuitry 606 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 608, and provide baseband signals to the baseband circuitry 604. The RF circuitry 606 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 604, and provide RF output signals to the FEM circuitry 608 for transmission.

[0059] In some embodiments, the RF circuitry 606 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 606 may include mixer circuitry 606A, amplifier circuitry 606B, and filter circuitry 606C. The transmit signal path of the RF circuitry 606 may include filter circuitry 606C and mixer circuitry 606A. The RF circuitry 606 may further include synthesizer circuitry 606D configured to synthesize a frequency for use by the mixer circuitry 606A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 606A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 608 based on the synthesized frequency provided by synthesizer circuitry 606D. The amplifier circuitry 606B may be configured to amplify the down-converted signals.

[0060] The filter circuitry 606C 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 604 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 606A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0061] In some embodiments, the mixer circuitry 606A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 606D to generate RF output signals for the FEM circuitry 608. The baseband signals may be provided by the baseband circuitry 604 and may be filtered by filter circuitry 606C. The filter circuitry 606C may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect. In some embodiments, the mixer circuitry 606A of the receive signal path and the mixer circuitry 606A 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 606A of the receive signal path and the mixer circuitry 606A 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 606A of the receive signal path and the mixer circuitry 606A may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 606A of the receive signal path and the mixer circuitry 606A of the transmit signal path may be configured for super-heterodyne operation.

[0062] 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 606 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and the baseband circuitry 604 may include a digital baseband interface to communicate with the RF circuitry 606.

[0063] In some dual-mode embodiments, separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0064] In some embodiments, the synthesizer circuitry 606D 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, synthesizer circuitry 606D 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.

[0065] The synthesizer circuitry 606D may be configured to synthesize an output frequency for use by the mixer circuitry 606A of the RF circuitry 606 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 606D may be a fractional $N/N+1$ synthesizer.

[0066] 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 604 or the applications processor 602 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 applications processor 602.

[0067] The synthesizer circuitry 606D of the RF circuitry 606 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.

[0068] In some embodiments, the synthesizer circuitry 606D 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 (f_{LO}). In some embodiments, the RF circuitry 606 may include an IQ/polar converter.

[0069] The FEM circuitry 608 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 610, amplify the received signals, and provide the amplified versions of the received signals to the RF

circuitry 606 for further processing. The FEM circuitry 608 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 606 for transmission by at least one of the one or more antennas 610.

[0070] In some embodiments, the FEM circuitry 608 may include a TX/RX switch configured to switch between a transmit mode and a receive mode operation. The FEM circuitry 608 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 608 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 606). The transmit signal path of the FEM circuitry 608 may include a power amplifier (PA) configured to amplify input RF signals (e.g., provided by RF circuitry 606), 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 610).

[0071] In some embodiments, the MS device 600 may include additional elements such as, for example, memory/storage, a display, a camera, one of more sensors, an input/output (I/O) interface, other elements, and combinations thereof.

[0072] In some embodiments, the MS device 600 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof.

[0073] FIG. 7 is a flow chart illustrating a method for performing operations of a mobile edge computing (MEC) node. The method 700 can be accomplished by systems such as those shown in FIG. 2, including the MEC node and the RAN node communicating over the control plane interface NGx. In block 702, the MEC node generates a request for a radio network information (RNI) measurement report from the MEC node for transmission using a MEC control plane interface to a radio access network (RAN) node. In block 704, the MEC node processes the RNI measurement report received in response to the request to the RAN node using the MEC control plane interface. In block 706, the MEC node applies a policy based at least in part on the RNI measurement report from the RAN node.

[0074] FIG. 8 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. 8 shows a diagrammatic representation of hardware resources 800 including one or more processors (or processor cores) 810, one or more memory/storage devices 820, and one or more communication resources 830, each of which are communicatively coupled via a bus 840.

[0075] The processors 810 (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 812 and a processor 814. The memory/storage devices 820 may include main memory, disk storage, or any suitable combination thereof.

[0076] The communication resources 830 may include interconnection and/or network interface components or other suitable devices to communicate with one or more peripheral devices 804 and/or one or more databases 806 via a network 808. For example, the communication resources 830 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.

[0077] Instructions 850 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 810 to perform any one or more of the methodologies discussed herein. The instructions 850 may reside, completely or partially, within at least one of the processors 810 (e.g., within the processor's cache memory), the memory/storage devices 820, or any suitable combination thereof.

Furthermore, any portion of the instructions 850 may be transferred to the hardware resources 800 from any combination of the peripheral devices 804 and/or the databases 806.

Accordingly, the memory of processors 810, the memory/storage devices 820, the peripheral devices 804, and the databases 806 are examples of computer-readable and machine-readable media.

Examples

[0078] The following examples pertain to further embodiments.

[0079] Example 1 is an apparatus. The apparatus is a radio access network (RAN) node supporting mobile edge computing (MEC), includes storage designed to store radio network information (RNI) measurement data. The apparatus is a radio access network (RAN) node supporting mobile edge computing (MEC), includes a processor attached to the storage, the processor designed to: process a request for RNI measurement data from a MEC server using a MEC control plane interface (NGx), and generate a report for the MEC server based at least in part on the request.

[0080] Example 2 is the apparatus of Example 1, where the processor is further designed to establish a session with the MEC server using a Diameter based protocol with the RAN node acting as a Diameter server.

[0081] Example 3 is the apparatus of Example 1, where the request is a NGx status request message.

[0082] Example 4 is the apparatus of Example 1, where to generate the report further includes to generate an application identifier of NGx, a command code of RNI-Report-Answer and attribute-value-pair data.

[0083] Example 5 is the apparatus of Example 1, where the report is a NGx resource status response or a NGx resource status update.

[0084] Example 6 is the apparatus of any of Examples 1-5, where the RAN node is an enhanced node B (eNB) or a fifth generation enhanced node B (gNB).

[0085] Example 7 is the apparatus of any of Examples 1-5, where the processor is a baseband processor.

[0086] Example 8 is a method to perform operations of a mobile edge computing (MEC) node. The method includes generating a request for a radio network information (RNI) measurement report from the MEC node for transmission using a MEC control plane interface to a radio access network (RAN) node. The method includes processing the RNI measurement report received in response to the request to the RAN node using the MEC control plane interface, and applying a policy based at least in part on the RNI measurement report from the RAN node.

[0087] Example 9 is the method of Example 8, where applying the policy further includes generating a message to a hosted application associated with the MEC node that includes data from the RNI measurement report.

[0088] Example 10 is the method of Example 9, where generating the message to the hosted application on the MEC node further includes processing a host request from the hosted application through a representational state transfer application programming interface (RESTful API), and generating a host response to the request using the RESTful API.

[0089] Example 11 is the method of Example 10, where the request and response are performed using a hypertext transfer protocol (HTTP).

[0090] Example 12 is the method of Example 8, where applying the policy further includes performing traffic analysis using data from the RNI measurement report to determine application usage that exceeds a threshold and enable local application server support for an application associated with the application usage.

[0091] Example 13 is the method of Example 8, where applying the policy further includes performing traffic analysis using data from the RNI measurement report to determine content usage that exceeds a threshold and enable local caching for the content or content downscaling.

[0092] Example 14 is the method of Example 8, where applying the policy further includes performing traffic analysis and providing local content delivery without use of a core network.

[0093] Example 15 is the method of Example 8, where applying the policy further includes performing traffic analysis using data from the RNI measurement report to determine cell load and apply one or more policies per user equipment (UE) per application.

[0094] Example 16 is the method of Example 8, where applying the policy further includes determining that the MEC node indicates an overload or congestion condition based at least in part on a number of internet protocol (IP) flows or user equipment served by the MEC node, triggering offloading of traffic, forwarding the traffic to a core network, or dropping IP packets.

[0095] Example 17 is the method of Example 8, where the RNI measurement report from the RAN node to the MEC node includes IP address information for UE identity, enabling the MEC node to use an IP address when providing RNI measurement data to a MEC hosted application associated with the MEC node.

[0096] Example 18 is an apparatus including manner to perform a method as exemplified in any of Examples 8-17.

[0097] Example 19 is a machine-readable storage including machine-readable instructions, when executed, to implement a method or realize an apparatus as exemplified in any of Examples 8-17.

[0098] Example 20 is a machine readable medium including code that, when executed, causes a machine to perform the method of any one of Examples 8-17.

[0099] Example 21 is a cellular node supporting mobile edge computing (MEC). The cellular node includes a wireless interface designed to communicate with one or more user equipment (UEs), a MEC control plane interface designed to provide a radio network information (RNI) application program interface (API) to a MEC server, and a user plane interface attached to the MEC server, the MEC server attached in a network between the cellular node and a core network. The cellular node includes storage for RNI measurement data. The cellular node includes one or more processing units attached to the wireless interface and the MEC control plane interface and designed to construct RNI measurement

data based at least in part on communication with the one or more UEs using the wireless interface, process an API request for the RNI measurement data from the MEC server from the MEC control plane interface. The cellular node includes one or more processing units attached to the wireless interface and the MEC control plane interface and designed to generate a report for the MEC server based at least in part on the API request, and transmit the report to the MEC server using the MEC control plane interface.

[0100] Example 22 is the cellular node of Example 21, where the RNI measurement data is physical resource block usage (PRB), number of active UEs per quality of service class indicator (QCI), packet delay, data loss, scheduled internet protocol (IP) throughput, or Data Volume.

[0101] Example 23 is the cellular node of Example 21, where the RNI measurement data is provided per cellular node, per cell, per UE, per quality of service class indicator (QCI), per bearer or per IP flow.

[0102] Example 24 is the cellular node of Example 21, where the MEC control plane interface is a NGx interface.

[0103] Example 25 is the cellular node of Example 21, where to generate the report further includes to periodically generate the report for the MEC server, and where to transmit the report further includes to periodically transmit the periodically generated report.

[0104] Example 26 is the cellular node of any of Examples 21-25, where the cellular node is an enhanced node B (eNB).

[0105] Example 27 is the cellular node of any of Examples 21-25, where the cellular node is a fifth generation enhanced node B (gNB).

[0106] Example 28 is an apparatus of a mobile edge computing (MEC) node. The apparatus includes a local network interface designed to offload traffic before reaching a core network and a MEC-radio access network (RAN) control plane interface designed to be attached to a RAN node. The apparatus includes a core network user plane interface designed to be attached to the core network and a RAN user plane interface designed to be attached to a RAN node. The apparatus includes storage for radio network information (RNI) data. The apparatus includes a processor, attached to the local network interface, the MEC-RAN control plane interface, the core network user plane interface, the RAN user plane interface and the storage, the processor designed to: generate an API request for RNI measurement data from the MEC node from the MEC-RAN control plane interface, process a report comprising the RNI measurement data for the MEC node based at least in part on the API request, and apply a policy based at least in part on the RNI measurement data.

[0107] Example 29 is the apparatus of Example 28, where the local network interface is attached to a third-party application; and where to apply the policy further includes to pass RNI information to the third-party application.

[0108] Example 30 is the apparatus of Example 28, where the report indicates core network congestion, and where to apply the policy further includes to provide proactive caching.

[0109] Example 31 is the apparatus of Example 28, where the report indicates RAN node congestion and where to apply the policy further includes to provide content scaling.

[0110] Example 32 is the apparatus of Example 28, where to apply the policy further includes to provide local content delivery.

[0111] Example 33 is the apparatus of Example 28, where to apply the policy further includes to apply rate policing.

[0112] Example 34 is a computer program product including a computer-readable storage medium that stores instructions for execution by a processor to perform operations of a mobile edge computing (MEC) node, the operations, when executed by the processor, to perform a method. The method includes generating a request for a radio network information (RNI) measurement report from the MEC node for transmission using a MEC control plane interface to a radio access network (RAN) node. The method includes processing the RNI measurement report received in response to the request to the RAN node using the MEC control plane interface, and applying a policy based at least in part on the RNI measurement report from the RAN node.

[0113] Additional Examples

[0114] Additional Example 1 is an Evolved Node B (eNB) comprising a radio interface to the UE and a network interface to the MEC server to communicate radio network interface (RNI) information.

[0115] Additional Example 2 is the eNB of claim 1, wherein the network interface is configured to communicate RNI information periodically or based on an event.

[0116] Additional Example 3 is the eNB of claim 1, wherein the RNI information comprises per eNB information, per cell information, per UE information, or per IP flow information.

[0117] Additional Example 4 is a MEC server, comprising a Traffic Offload Function (TOF) and a network interface to the eNB to receive RNI information

[0118] Additional Example 5 is the MEC server of claim 4, further configured to perform an offload and scheduling decisions based on the RNI information received via the said network interface.

[0119] Embodiments and implementations of the systems and methods described herein may include various operations, which may be embodied in machine-executable instructions to be executed by a computer system. A computer system may include one or more general-purpose or special-purpose computers (or other electronic devices). The computer system may include hardware components that include specific logic for performing the operations or may include a combination of hardware, software, and/or firmware.

[0120] Computer systems and the computers in a computer system may be connected via a network. Suitable networks for configuration and/or use as described herein include one or more local area networks, wide area networks, metropolitan area networks, and/or Internet or IP networks, such as the World Wide Web, a private Internet, a secure Internet, a value-added network, a virtual private network, an extranet, an intranet, or even stand-alone machines which communicate with other machines by physical transport of media. In particular, a suitable network may be formed from parts or entirety of two or more other networks, including networks using disparate hardware and network communication technologies.

[0121] One suitable network includes a server and one or more clients; other suitable networks may contain other combinations of servers, clients, and/or peer-to-peer nodes, and a given computer system may function both as a client and as a server. Each network includes at least two computers or computer systems, such as the server and/or clients. A computer system may include a workstation, laptop computer, disconnectable mobile computer, server, mainframe, cluster, so-called “network computer” or “thin client,” tablet, smart phone, personal digital assistant or other hand-held computing device, “smart” consumer electronics device or appliance, medical device, or a combination thereof.

[0122] Suitable networks may include communications or networking software, such as the software available from Novell®, Microsoft®, and other vendors, and may operate using TCP/IP, SPX, IPX, and other protocols over twisted pair, coaxial, or optical fiber cables, telephone lines, radio waves, satellites, microwave relays, modulated AC power lines, physical media transfer, and/or other data transmission “wires” known to those of skill in the art. The network may encompass smaller networks and/or be connectable to other networks through a gateway or similar mechanism.

[0123] 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, magnetic or optical cards, solid-state memory devices, a nontransitory 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 nonvolatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and nonvolatile memory and/or storage elements may be a RAM, an EPROM, a flash drive, an optical drive, a magnetic hard drive, or other medium for storing electronic data. The eNB (or other base station or RAN node) 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 interpreted language, and combined with hardware implementations.

[0124] Each computer system includes one or more processors and/or memory; computer systems may also include various input devices and/or output devices. The processor may include a general purpose device, such as an Intel®, AMD®, or other “off-the-shelf” microprocessor. The processor may include a special purpose processing device, such as ASIC, SoC, SiP, FPGA, PAL, PLA, FPLA, PLD, or other customized or programmable device. The memory may include static RAM, dynamic RAM, flash memory, one or more flip-flops, ROM, CD-ROM, DVD, disk, tape, or magnetic, optical, or other computer storage medium. The input device(s) may include a keyboard, mouse, touch screen, light pen, tablet, microphone, sensor, or other hardware with accompanying firmware and/or software. The output device(s) may include a monitor or other display, printer, speech or text synthesizer, switch, signal line, or other hardware with accompanying firmware and/or software.

[0125] 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, or 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.

[0126] 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.

[0127] 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 active, including agents operable to perform desired functions.

[0128] Several aspects of the embodiments described will be illustrated as software modules or components. As used herein, a software module or component may include any type of computer instruction or computer-executable code located within a memory device. A software module may, for instance, include one or more physical or logical blocks of computer instructions, which may be organized as a routine, program, object, component, data structure, etc., that perform one or more tasks or implement particular data types. It is appreciated that a software module may be implemented in hardware and/or firmware instead of or in addition to software. One or more of the functional modules described herein may be separated into sub-modules and/or combined into a single or smaller number of modules.

[0129] In certain embodiments, a particular software module may include disparate instructions stored in different locations of a memory device, different memory devices, or different computers, which together implement the described functionality of the module. Indeed, a module may include a single instruction or many instructions, and may be distributed over several different code segments, among different programs, and across several memory devices. Some embodiments may be practiced in a distributed computing

environment where tasks are performed by a remote processing device linked through a communications network. In a distributed computing environment, software modules may be located in local and/or remote memory storage devices. In addition, data being tied or rendered together in a database record may be resident in the same memory device, or across several memory devices, and may be linked together in fields of a record in a database across a network.

[0130] 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.

[0131] 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.

[0132] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of materials, frequencies, sizes, lengths, widths, shapes, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that the embodiments may be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects.

[0133] It should be recognized that the systems described herein include descriptions of specific embodiments. These embodiments can be combined into single systems, partially combined into other systems, split into multiple systems or divided or combined in other ways. In addition, it is contemplated that parameters/attributes/aspects/etc. of one embodiment can be used in another embodiment. The parameters/attributes/aspects /etc. are merely described in one or more embodiments for clarity, and it is recognized that the

parameters/attributes/aspects /etc. can be combined with or substituted for parameters/attributes/etc. of another embodiment unless specifically disclaimed herein.

[0134] 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 specification is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

[0135] Those having skill in the art will appreciate that many changes may be made to the details of the above-described embodiments without departing from the underlying principles. The scope of the present description should, therefore, be determined only by the following claims.

Claims:

1. An apparatus of a radio access network (RAN) node supporting mobile edge computing (MEC), comprising:
 - storage configured to store radio network information (RNI) measurement data;
 - a processor coupled to the storage, the processor configured to:
 - process a request for RNI measurement data from a MEC server using a MEC control plane interface (NGx); and
 - generate a report for the MEC server based at least in part on the request.
2. The apparatus of claim 1, wherein the processor is further configured to establish a session with the MEC server using a Diameter based protocol with the RAN node acting as a Diameter server.
3. The apparatus of claim 1, wherein the request is a NGx status request message.
4. The apparatus of claim 1, wherein to generate the report further comprises to generate an application identifier of NGx, a command code of RNI-Report-Answer and attribute-value-pair data.
5. The apparatus of claim 1, wherein the report is a NGx resource status response or a NGx resource status update.
6. The apparatus of any of claims 1-5, wherein the RAN node is an enhanced node B (eNB) or a fifth generation enhanced node B (gNB).
7. The apparatus of any of claims 1-5, wherein the processor is a baseband processor.
8. A method to perform operations of a mobile edge computing (MEC) node, the method comprising:
 - generating a request for a radio network information (RNI) measurement report from the MEC node for transmission using a MEC control plane interface to a radio access network (RAN) node;
 - processing the RNI measurement report received in response to the request to the RAN node using the MEC control plane interface; and

applying a policy based at least in part on the RNI measurement report from the RAN node.

9. The method of claim 8, wherein applying the policy further comprises generating a message to a hosted application associated with the MEC node that includes data from the RNI measurement report.

10. The method of claim 9, wherein generating the message to the hosted application on the MEC node further comprises:

processing a host request from the hosted application through a representational state transfer application programming interface (RESTful API); and
generating a host response to the request using the RESTful API.

11. The method of claim 10, wherein the request and response are performed using a hypertext transfer protocol (HTTP).

12. The method of claim 8, wherein applying the policy further comprises performing traffic analysis using data from the RNI measurement report to determine application usage that exceeds a threshold and enable local application server support for an application associated with the application usage.

13. The method of claim 8, wherein applying the policy further comprises performing traffic analysis using data from the RNI measurement report to determine content usage that exceeds a threshold and enable local caching for the content or content downscaling.

14. The method of claim 8, wherein applying the policy further comprises performing traffic analysis and providing local content delivery without use of a core network.

15. The method of claim 8, wherein applying the policy further comprises performing traffic analysis using data from the RNI measurement report to determine cell load and apply one or more policies per user equipment (UE) per application.

16. The method of claim 8, wherein applying the policy further comprises determining that the MEC node indicates an overload or congestion condition based at least in part on a number of internet protocol (IP) flows or user equipment served by the MEC node; and

triggering offloading of traffic;
forwarding the traffic to a core network; or
dropping IP packets.

17. The method of claim 8, wherein the RNI measurement report from the RAN node to the MEC node includes IP address information for UE identity, enabling the MEC node to use an IP address when providing RNI measurement data to a MEC hosted application associated with the MEC node.

18. An apparatus comprising means to perform a method as claimed in any of claims 8-17.

19. Machine-readable storage including machine-readable instructions, when executed, to implement a method or realize an apparatus as claimed in any of claims 8-17.

20. A machine readable medium including code that, when executed, causes a machine to perform the method of any one of claims 8-17.

21. An apparatus of a mobile edge computing (MEC) node, comprising:
a local network interface configured to offload traffic before reaching a core network;
a MEC-radio access network (RAN) control plane interface configured to be coupled to a RAN node;
a core network user plane interface configured to be coupled to the core network;
a RAN user plane interface configured to be coupled to a RAN node;
storage for radio network information (RNI) data;
a processor, coupled to the local network interface, the MEC-RAN control plane interface, the core network user plane interface, the RAN user plane interface and the storage, the processor configured to:

generate an API request for RNI measurement data from the MEC node from the MEC-RAN control plane interface;

process a report comprising the RNI measurement data for the MEC node based at least in part on the API request; and

apply a policy based at least in part on the RNI measurement data.

22. The apparatus of claim 21, wherein the local network interface is coupled to a third-party application; and wherein to apply the policy further comprises to pass RNI information to the third-party application.

23. The apparatus of claim 21, wherein the report indicates core network congestion, and wherein to apply the policy further comprises to provide proactive caching.

24. The apparatus of claim 21, wherein the report indicates RAN node congestion and wherein to apply the policy further comprises to provide content scaling.

25. The apparatus of claim 21, wherein to apply the policy further comprises to provide local content delivery.

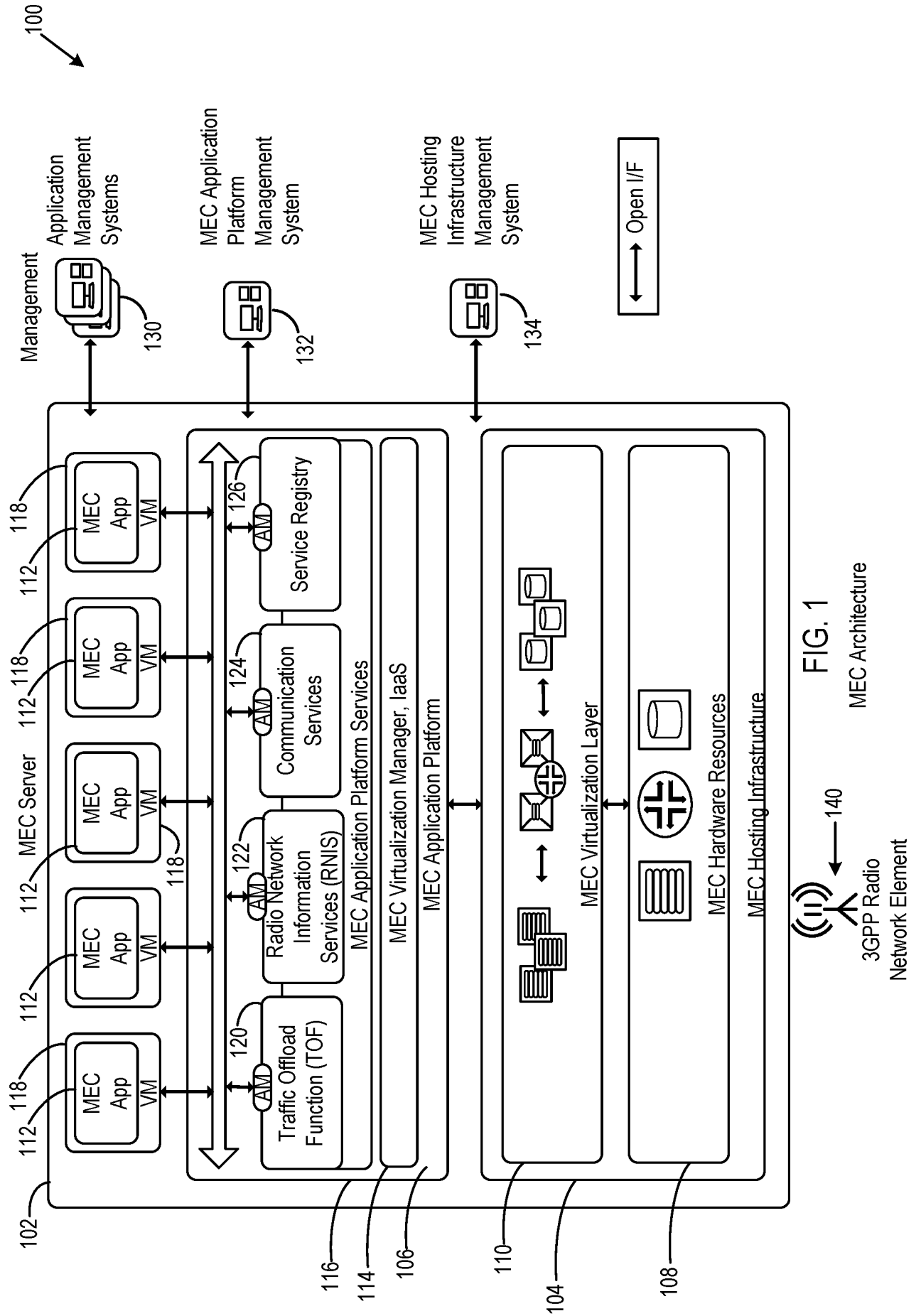


FIG. 1

MEC Architecture

200

300
↘

Application Identifier	NGx		
Command Code	RNI-Report-Request/Answer		
AVP Codes	Attribute Name	Data Type	
	RNI-Data	OctetString	

Definitions for RNI Report

FIG. 3

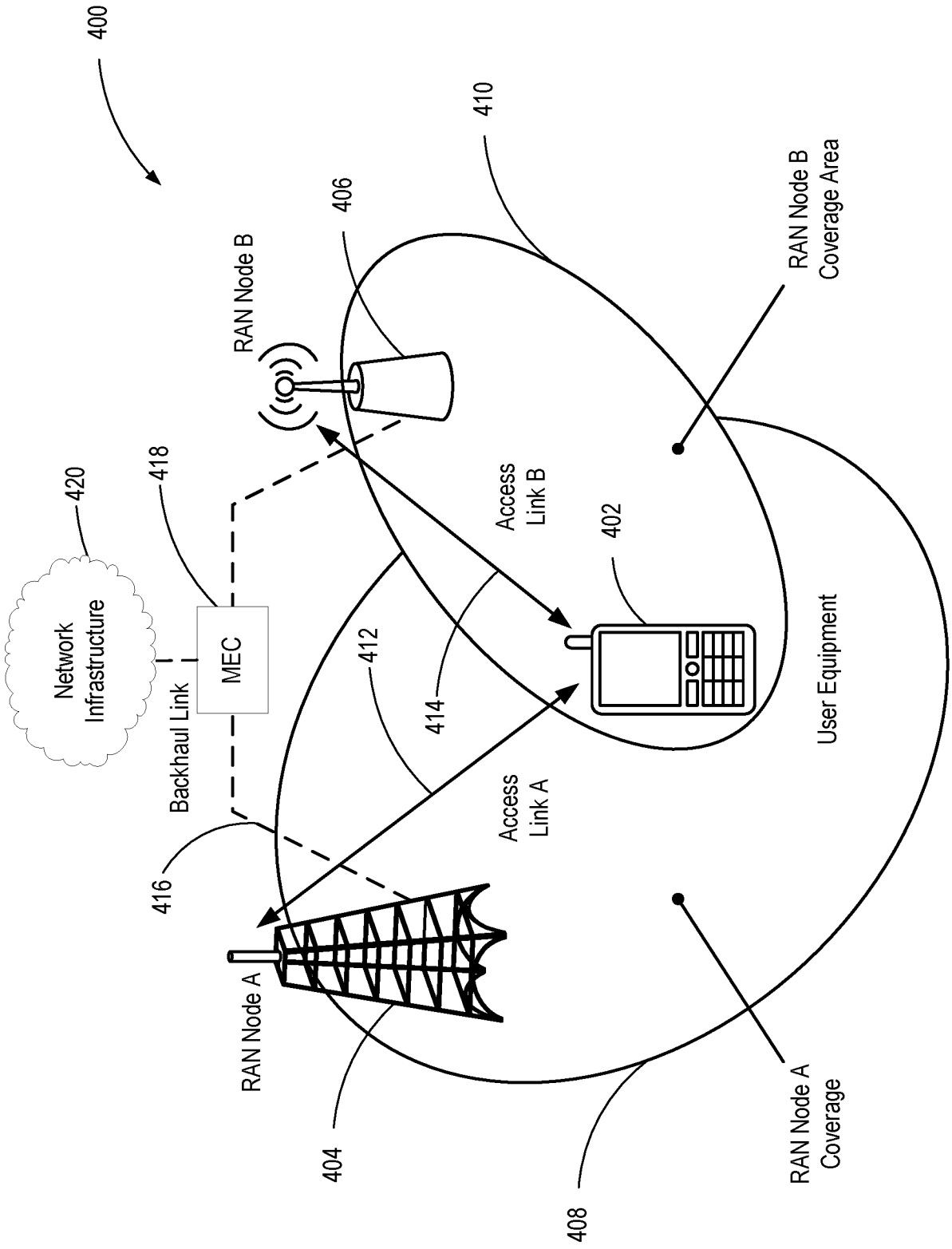


FIG. 4

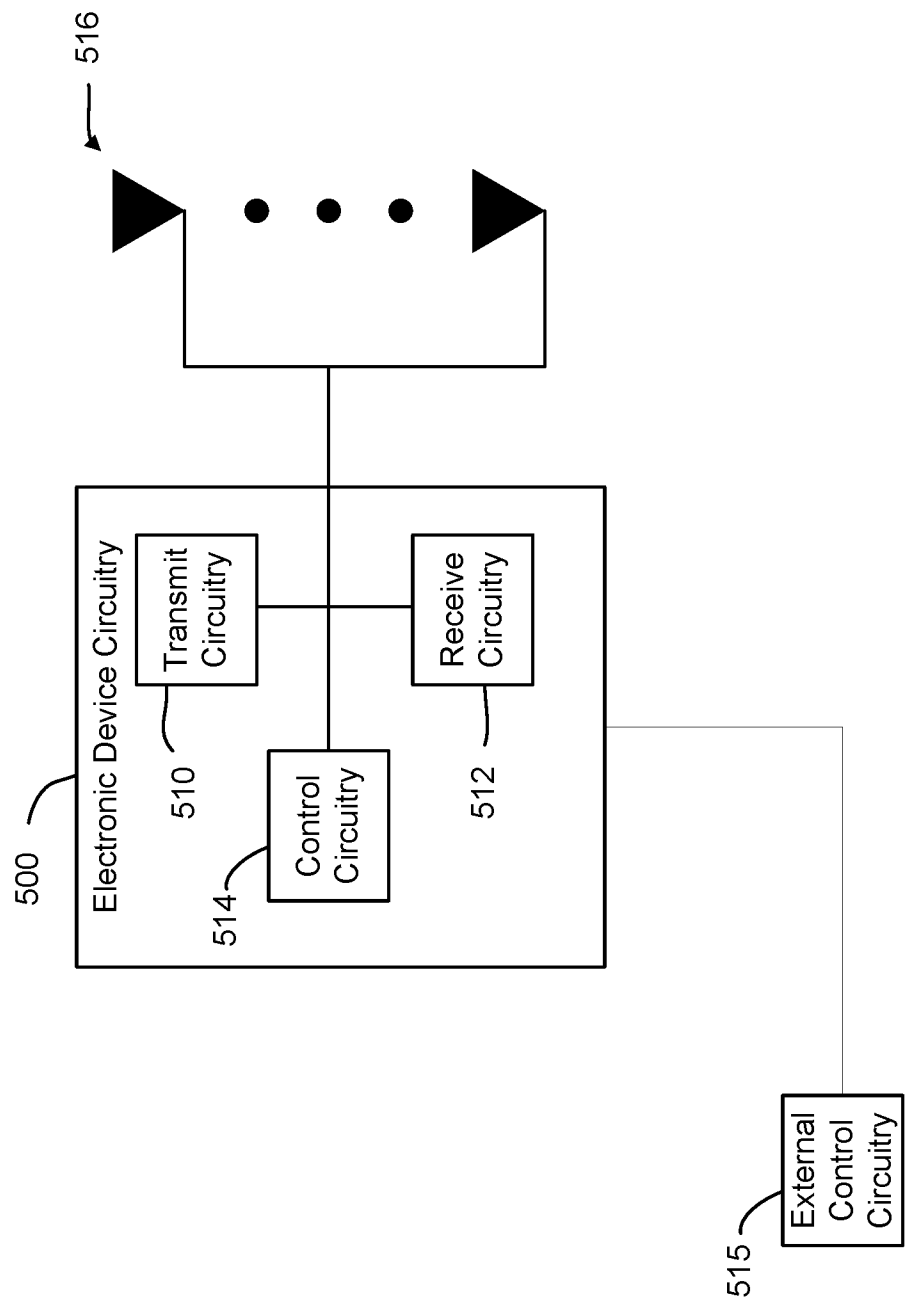


FIG. 5

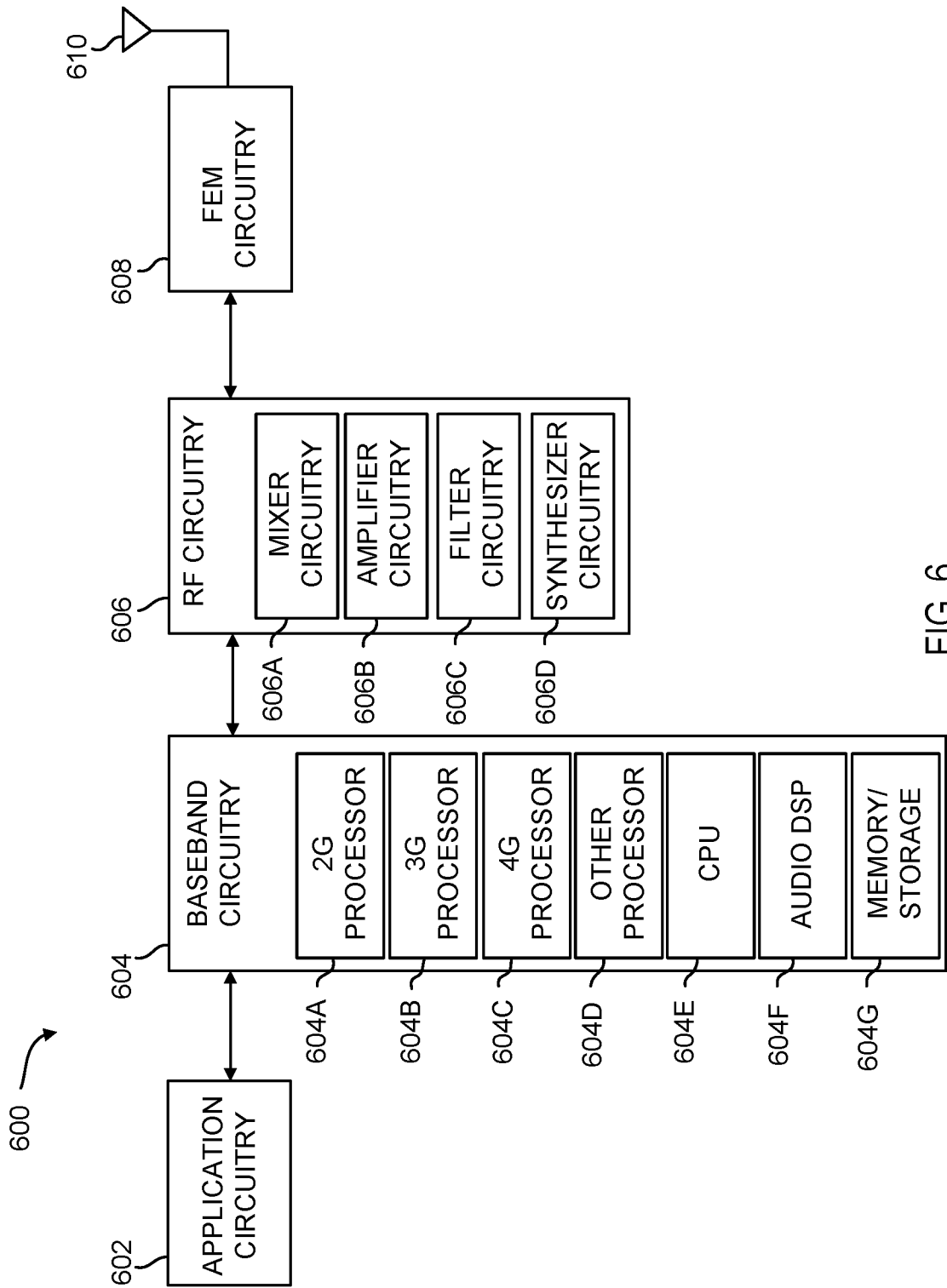


FIG. 6

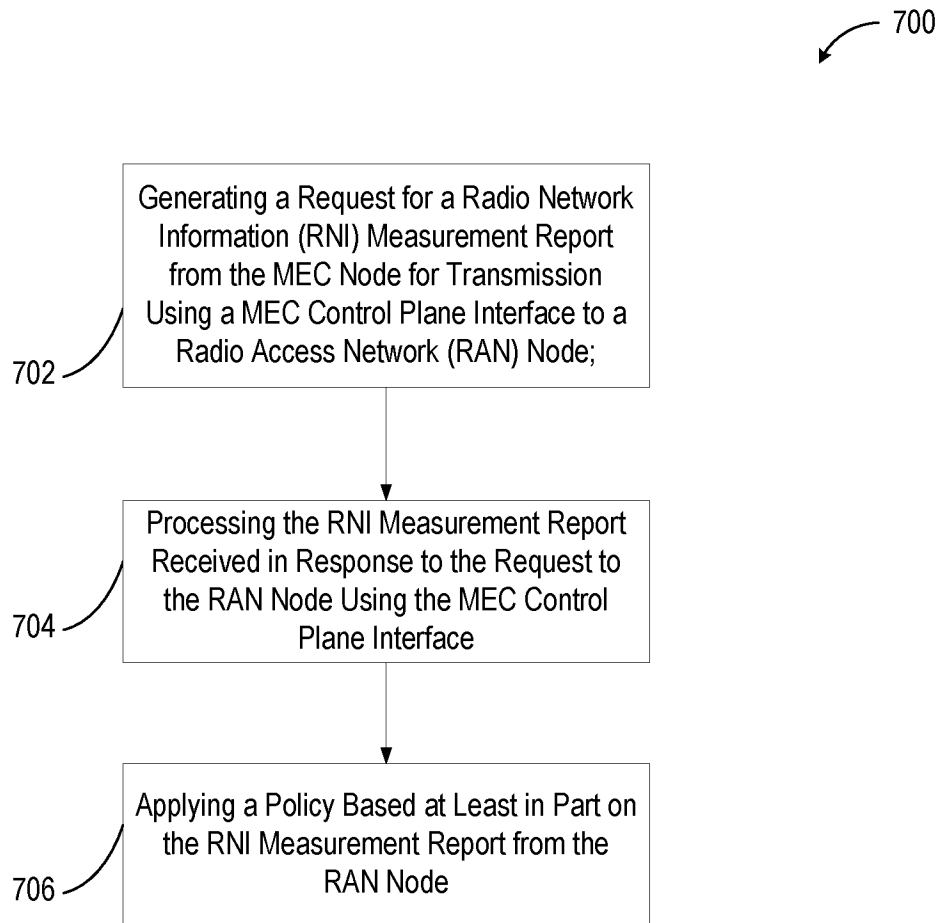


FIG. 7

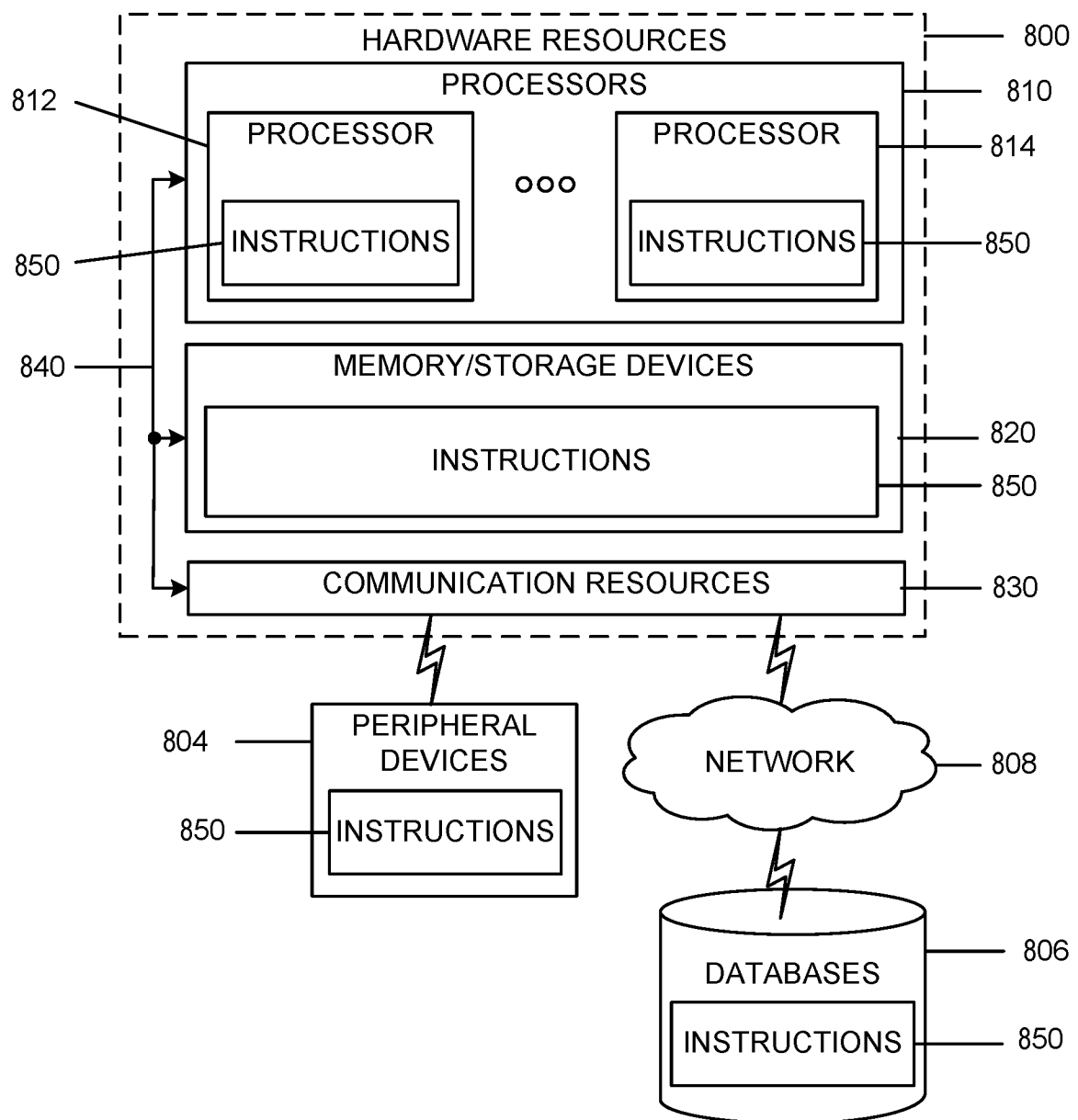


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/020737

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H04W36/12 H04W8/08
 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)
 H04W

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

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

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	INTEL CORPORATION: "Local Breakout for Ultra-Low Latency Communications", 3GPP DRAFT; R3-161074-ULTRA-LOW LATENCY COMMUNICATIONS V02, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG3, no. Nanjing, P.R. China; 20160523 - 20160527 14 May 2016 (2016-05-14), XP051094688, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG3_Iu/TSGR3_92/Docs/ [retrieved on 2016-05-14] Option B; paragraph [04.2] Option D; -/--	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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"&" document member of the same patent family

Date of the actual completion of the international search

7 June 2017

Date of mailing of the international search report

23/06/2017

Name and mailing address of the ISA/

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Authorized officer

Roberti, Vincenzo

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/020737

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	paragraph [04.2] paragraph [0010]; figures C-2, C-4 ----- SAGUNA ET AL: "Use Case: MEC Virtualized IP Flow Mobility Function; MEC(15)000117a1r2 Use Case_MEC_Virtualized_IP_Flow_Mobility_Function", ETSI DRAFT; MEC(15)000117A1R2 USE CASE_MEC_VIRTUALIZED_IP_FLOW_MOBILITY_FUNCTION, EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI), 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS ; FRANCE, vol. ISG - MEC, 30 June 2015 (2015-06-30), pages 1-2, XP014250137, abstract Use of MEC; paragraph [A.x.2] -----	1-25
X	"Mobile-Edge Computing; Mobile-edge Computing - Introductory Technical White Paper V1 18-09-14", ETSI DRAFT; MOBILE-EDGE COMPUTING - INTRODUCTORY TECHNICAL WHITE PAPER V1 18-09-14, EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI), 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS ; FRANCE, vol. LI - LI am, 16 December 2014 (2014-12-16), pages 1-36, XP014232595, paragraph [05.1]; figure 9 paragraph [5.1.1.2] paragraph [5.1.1.3] -----	1-25
A	"Support of 3GPP measurements for Mobile Edge Computing", 3GPP DRAFT; R3-161378 MEC(16)000206R1 LSOUT ON SUPPORT OF 3GPP MEASUREMENTS FOR MOBILE EDGE CO, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 , vol. RAN WG3, no. Nanjing, China; 20160523 - 20160527 22 May 2016 (2016-05-22), XP051106203, Retrieved from the Internet: URL: http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN3/LSin/ [retrieved on 2016-05-22] the whole document -----	1-25