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(54) **Title:** METHOD AND APPARATUS FOR SELECTING LAG PORT FOR IP FLOW

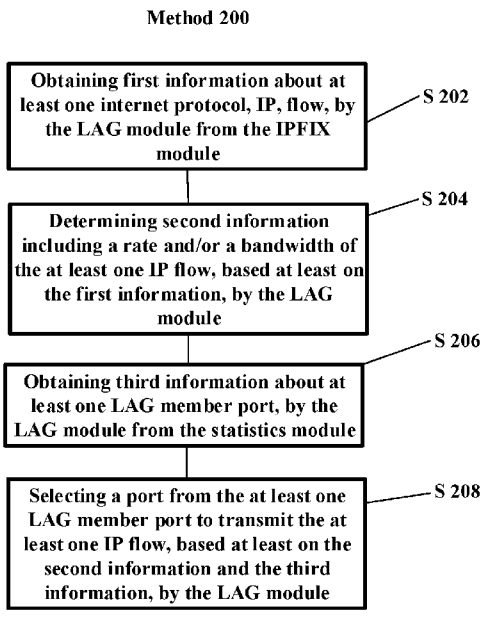

FIG. 2A

(57) **Abstract:** Embodiments of the present disclosure provide a method and an apparatus for selecting LAG port for IP flow. The network node may comprise: a LAG module, an IPFIX module, and a statistics module. The method (200) may comprises: obtaining (S202) first information about at least one IP flow, by the LAG module from the IPFIX module; determining (S204) second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information, by the LAG module; obtaining (S206) third information about at least one LAG member port, by the LAG module from the statistics module; and selecting (S208) a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information, by the LAG module.

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METHOD AND APPARATUS FOR SELECTING LAG PORT FOR IP FLOW

TECHNICAL FIELD

[0001] The present disclosure relates generally to the technology of communication, and in particular, to a method and an apparatus for selecting a link aggregation group (LAG) port for an internet protocol (IP) flow.

BACKGROUND

[0002] This section introduces aspects that may facilitate better understanding of the present disclosure. Accordingly, the statements of this section are to be read in this light and are not to be understood as admissions about what is in the prior art or what is not in the prior art.

[0003] In communication network, many technologies are applied to improve the performance (such as transmission rate) of data transmission.

[0004] For example, an IEEE (Institute of Electrical and Electronics Engineers) standard, IEEE 802.3ad Link Aggregation, allows parallel point-to-point links to be used as if they were a single link, and also supports the use of multiple links as a resilient load-sharing interconnect between multiple nodes in two separately administered networks. This standard defines a MAC (media access control)-independent Link Aggregation capability and provides general information relevant to specific MAC types.

SUMMARY

[0005] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

[0006] When Link Aggregation is utilized, a data flow (such as an IP flow) to be transmitted may be forwarded to one port selected from a plurality of LAG member ports. Usually, the principle for mapping an IP flow to a port is predetermined and stored. When one high rate IP flow or some concurrent IP flows are mapped to one port according to such predetermined principle, the transmission capability of that port may be not enough for transmitting such IP flows.

[0007] Certain aspects of the present disclosure and their embodiments may provide solutions to these or other challenges. There are, proposed herein, various embodiments which address one or more of the issues disclosed herein. Specific method and apparatus for selecting LAG port for IP flow may be provided. Congestion status on LAG member port in some scenario may be eliminated or at least reduced.

[0008] A first aspect of the present disclosure provides a method performed by a network node. The network node may comprise: a link aggregation group (LAG) module, an internet protocol flow information export (IPFIX) module, and a statistics module. The method may comprise: obtaining first information about at least one internet protocol (IP) flow, by the LAG module from the IPFIX module;

determining second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information, by the LAG module; obtaining third information about at least one LAG member port, by the LAG module from the statistics module; and selecting a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information, by the LAG module.

[0009] In embodiments of the present disclosure, the network node may further comprise an access control list, ACL, module. The method may further comprise: sending the selected port, by the LAG module to the ACL module, to update an egress ACL.

[0010] In embodiments of the present disclosure, the first information may comprise at least one of: IP tuples, a source port, a destination port, a packet number, or bytes for the at least one IP flow.

[0011] In embodiments of the present disclosure, the third information may comprise: a status of congestion and/or bandwidth utilization on each port of the at least one LAG member port.

[0012] In embodiments of the present disclosure, the status of congestion and/or bandwidth utilization may be obtained, based on a counter and/or a rate on each port of the at least one LAG member port.

[0013] In embodiments of the present disclosure, a port with less congestion and/or less bandwidth utilization may be selected for the at least one IP flow with higher rate.

[0014] In embodiments of the present disclosure, a port with a bandwidth utilization less than a threshold may be selected for the at least one IP flow.

[0015] In embodiments of the present disclosure, a free port may be selected for the at least one IP flow.

[0016] In embodiments of the present disclosure, the network node may comprise a switcher or a router.

[0017] A second aspect of the present disclosure provides an apparatus for a network node in a communication network. The apparatus may comprise: a LAG module, an IPFIX module, and a statistics module. The LAG module is configured to: obtain first information about at least one internet protocol (IP) flow, from the IPFIX module; determine second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information; obtain third information about at least one LAG member port, from the statistics module; and select a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information.

[0018] In embodiments of the present disclosure, the apparatus may be further operative to perform the method according to any of above embodiments.

[0019] A third aspect of the present disclosure provides computer-readable storage medium storing instructions, which when executed by at least one processor, cause the at least one processor to perform the method according to any of above embodiments.

[0020] Embodiments herein afford many advantages. According to embodiments of the present disclosure, an improved manner for selecting LAG port for IP flow may be provided.

[0021] Particularly, a LAG port may be selected for IP flow dynamically, based on information about

the LAG port and/or the IP flow. Therefore, a congestion status on LAG member port in some scenario may be eliminated or at least reduced.

[0022] Further, according to embodiments of the present disclosure, the traffic loss on egress of LAG member port may be avoided. The bandwidth utilization of LAG may be improved. Automatically adjustment without manual operation and interference may be achieved.

BRIEF DESCRIPTION OF DRAWINGS

[0023] The above and other aspects, features, and benefits of various embodiments of the present disclosure will become more fully apparent, by way of example, from the following detailed description with reference to the accompanying drawings, in which like reference numerals or letters are used to designate like or equivalent elements. The drawings are illustrated for facilitating better understanding of the embodiments of the disclosure and not necessarily drawn to scale, in which:

[0024] FIG. 1A is a diagram depicting a common case where Aggregation Ports in a system are supported directly by a MAC.

[0025] FIG. 1B is a diagram showing the procedure of packets forwarding to LAG.

[0026] FIG. 1C is a diagram showing one example of congestion and traffic loss on LAG member port.

[0027] FIG. 2A is a flow chart illustrating a method performed by a network node, in accordance with some embodiments of the present disclosure.

[0028] FIG. 2B is a flow chart illustrating a further step of the method in FIG. 2A, in accordance with some embodiments of the present disclosure.

[0029] FIG. 3 is a schematic showing units for the exemplary apparatus for a network node, according to embodiments of the present disclosure.

[0030] FIG. 4 is a diagram showing the improved procedure of packets forwarding to LAG, according to embodiments of the present disclosure.

[0031] FIG. 5 is a function diagram illustrating further detailed embodiments of the present disclosure.

[0032] FIG. 6 is a diagram showing a routine operation procedure in LAG module, according to embodiments of the present disclosure.

[0033] FIG. 7 is a diagram showing a predetermined threshold for bandwidth utilization of LAG member port, according to embodiments of the disclosure.

[0034] FIG. 8 is a block diagram showing an exemplary apparatus for a network node, which is suitable for perform the method according to embodiments of the disclosure.

[0035] FIG. 9 is a block diagram showing an apparatus/computer readable storage medium, according to embodiments of the present disclosure.

[0036] FIG. 10 shows an example of a communication system 1000 in accordance with some embodiments.

[0037] FIG. 11 shows a UE 1100 in accordance with some embodiments.

[0038] FIG. 12 shows a network node 1200 in accordance with some embodiments.

[0039] FIG. 13 is a block diagram of a host 1300, which may be an embodiment of the host 1016 of FIG. 10, in accordance with various aspects described herein.

[0040] FIG. 14 is a block diagram illustrating a virtualization environment 1400 in which functions implemented by some embodiments may be virtualized.

[0041] FIG. 15 shows a communication diagram of a host 1502 communicating via a network node 1504 with a UE 1506 over a partially wireless connection in accordance with some embodiments.

DETAILED DESCRIPTION

[0042] The embodiments of the present disclosure are described in detail with reference to the accompanying drawings. It should be understood that these embodiments are discussed only for the purpose of enabling those skilled persons in the art to better understand and thus implement the present disclosure, rather than suggesting any limitations on the scope of the present disclosure. Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present disclosure should be or are in any single embodiment of the disclosure. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present disclosure. Furthermore, the described features, advantages, and characteristics of the disclosure may be combined in any suitable manner in one or more embodiments. One skilled in the relevant art will recognize that the disclosure may be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the disclosure.

[0043] Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where it is implicit that a step must follow or precede another step. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features and advantages of the enclosed embodiments will be apparent from the following description.

[0044] As used herein, the term “network” or “communication network” refers to a network following any suitable communication standards (such for an internet network, or any wireless network). For example, wireless communication standards may comprise new radio (NR), long term evolution (LTE), LTE-Advanced, wideband code division multiple access (WCDMA), high-speed packet access (HSPA), Code Division Multiple Access (CDMA), Time Division Multiple Address (TDMA), Frequency Division Multiple Access (FDMA), Orthogonal Frequency-Division Multiple

Access (OFDMA), Single carrier frequency division multiple access (SC-FDMA) and other wireless networks. In the following description, the terms "network" and "system" can be used interchangeably. Furthermore, the communications between two devices in the network may be performed according to any suitable communication protocols, including, but not limited to, the wireless communication protocols as defined by a standard organization such as 3rd generation partnership project (3GPP) or the wired communication protocols.

[0045] The term "network node" used herein refers to a network device or network entity or network function or any other devices (physical or virtual) in a communication network. For example, the network node in the network may include a base station (BS), an access point (AP), a multi-cell/multicast coordination entity (MCE), a server node/function (such as a service capability server/application server, SCS/AS, group communication service application server, GCS AS, application function, AF), an exposure node/function (such as a service capability exposure function, SCEF, network exposure function, NEF), a unified data management, UDM, a home subscriber server, HSS, a session management function, SMF, an access and mobility management function, AMF, a mobility management entity, MME, a controller or any other suitable device in a wireless communication network. The BS may be, for example, a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a next generation NodeB (gNodeB or gNB), a remote radio unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth.

[0046] Yet further examples of the network node may comprise multi-standard radio (MSR) radio equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, positioning nodes and/or the like.

[0047] Further, the term "network node", "network function", "network entity" herein may also refer to any suitable node, function, entity which can be implemented (physically or virtually) in a communication network. For example, the 5G system (5GS) may comprise a plurality of NFs such as AMF (Access and mobility Function), SMF (Session Management Function), AUSF (Authentication Service Function), UDM (Unified Data Management), PCF (Policy Control Function), AF (Application Function), NEF (Network Exposure Function), UPF (User plane Function) and NRF (Network Repository Function), RAN (radio access network), SCP (service communication proxy), etc. In other embodiments, the network function may comprise different types of NFs (such as PCRF (Policy and Charging Rules Function), etc.) for example depending on the specific network.

[0048] The term "terminal device" refers to any end device that can access a communication network and receive services therefrom. By way of example and not limitation, the terminal device refers to a mobile terminal, user equipment (UE), or other suitable devices. The UE may be, for example, a Subscriber Station (SS), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a portable computer, an image capture terminal device such as a digital camera, a gaming terminal device, a music storage and a playback appliance, a mobile phone, a cellular phone, a smart phone, a voice over IP (VoIP) phone, a wireless

local loop phone, a tablet, a wearable device, a personal digital assistant (PDA), a portable computer, a desktop computer, a wearable terminal device, a vehicle-mounted wireless terminal device, a wireless endpoint, a mobile station, a laptop-embedded equipment (LEE), a laptop-mounted equipment (LME), a USB dongle, a smart device, a wireless customer-premises equipment (CPE) and the like. In the following description, the terms "terminal device", "terminal", "user equipment" and "UE" may be used interchangeably. As one example, a terminal device may represent a UE configured for communication in accordance with one or more communication standards promulgated by the 3GPP, such as 3GPP' LTE standard or NR standard. As used herein, a "user equipment" or "UE" may not necessarily have a "user" in the sense of a human user who owns and/or operates the relevant device. In some embodiments, a terminal device may be configured to transmit and/or receive information without direct human interaction. For instance, a terminal device may be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the communication network. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but that may not initially be associated with a specific human user.

[0049] As yet another example, in an Internet of Things (IoT) scenario, a terminal device may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another terminal device and/or network equipment. The terminal device may in this case be a machine-to-machine (M2M) device, which may in a 3GPP context be referred to as a machine-type communication (MTC) device. As one particular example, the terminal device may be a UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances, for example refrigerators, televisions, personal wearables such as watches etc. In other scenarios, a terminal device may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation.

[0050] References in the specification to "one embodiment," "an embodiment," "an example embodiment," and the like indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0051] It shall be understood that although the terms "first" and "second" etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or" includes any and all combinations

of one or more of the associated listed terms.

[0052] As used herein, the phrase "at least one of A and (or) B" should be understood to mean "only A, only B, or both A and B." The phrase "A and/or B" should be understood to mean "only A, only B, or both A and B."

[0053] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0054] It is noted that these terms as used in this document are used only for ease of description and differentiation among nodes, devices or networks etc. With the development of the technology, other terms with the similar/same meanings may also be used.

[0055] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0056] FIG. 1A is a diagram depicting a common case where Aggregation Ports in a system are supported directly by a MAC.

[0057] As shown in FIG. 1A, the Link Aggregation may be used in a system (such as in a router, or switcher) utilizing Open System Interface (OSI) Reference model. The OSI Reference model layers may include application layer, presentation layer, session layer, transport layer, network layer, data link layer, physical layer. The system may also utilize carrier sense multiple access/collision detection (CSMA/CD) layers. In data link layer, LLC (logical link control) or other aggregator client may utilize link aggregation sublayer.

[0058] FIG. 1A particularly shows architectural positioning of Link Aggregation sublayer. Link Aggregation provides protocols, procedures, and managed objects that allow the following: - one or more parallel instances of point-to-point links to be aggregated together to form a Link Aggregation Group (LAG) so that a Link Aggregation Client can treat the LAG as if it were a single link. For example, IEEE 802.3ad link aggregation enables Ethernet interfaces to be grouped to form a single link layer interface, also known as a link aggregation group (LAG) or bundle.

[0059] As one principle to assign data traffic to a port, packet hashing balances traffic over links at the packet level, while ensuring that flows are not split across links.

[0060] When dividing data traffic among the links of a link group, a router does not reorder flows and keeps each flow on the same constituent port. Egress traffic is balanced among all available links in the link group based on whether the circuit is packet-hashed.

[0061] For packet-hashing, load balancing uses a hash key and the distribution of link group constituent ports in the hash table. The hash key is computed for the packet from various packet header fields.

[0062] Generally, the L2 header and/or IP 5 tuples can be static selected as hash key of link group. User can choose different subset of these fields in packets as hash key and different hash algorithm when create and enable the link group.

[0063] Balancing is at its best when all ports in the link group are in the Up state, packets are the same size, and the set of input flows, as defined by the applicable hashing algorithm, hashes equally to different hash table rows. (In a lab environment this last condition is configured by building a sequence of flows with IP addresses varying by one.) Because the "best" conditions are not those found in networks, the more realistic goal of load balancing is not to distribute an even split of traffic but rather to ensure that distribution is adequate when hundreds of flows are egressing a link group.

[0064] When the abundant flows with different packets fields for packet hashing are forwarding to the LAG with several links. the outgoing traffic on LAG could be even on all LAG member ports.

[0065] When few flows with high speed are forwarding to the LAG, the congestion on LAG member port could happen when the packet hashing result of several flows are same, and the total rate of these flows is over the bandwidth of LAG member port.

[0066] FIG. 1B is a diagram showing the procedure of packets forwarding to LAG.

[0067] As shown in FIG. 1B, the procedure may include following steps: receiving packet; generating hash key from packet header fields; routing or switching packets to LAG; calculating the destination (outgoing LAG member port) according to the hash key and algorithm selected; and sending packet out from the (calculated) LAG member port.

[0068] FIG. 1C is a diagram showing one example of congestion and traffic loss on LAG member port.

[0069] As shown in FIG. 1C, two flows are received on different ports, such as port-1 and port-2. The IP 5 tuples are selected as hash key of this LAG. Unfortunately, the calculated results of LAG load balance algorithm of both flows are same, and LAG member Port-3 are selected for both flows. Because the speed of each flow is 10G, traffics with total speed of 20G are forwarded to Port-3, which only has 10G bandwidth. The congestion and traffic loss happen, even while the LAG member Port-4 is free.

[0070] In such issue, the traffic loss is not expected by user, since the whole bandwidth of LAG is not fully occupied yet.

[0071] However, in order for flows not to be split across links, the key for packet-hashing is based on fields of packet on flows, and the real congestion status is not involved into the calculation of packet-hashing.

[0072] The destination of flows in routing/switching are determined by L2 or L3 forwarding tables, however the selected destination LAG member port is only determined by packet hashing. Users can change the option of key for packet hashing manually, however, the congestion on LAG member port still could happen even when the fields in packets changes.

[0073] FIG. 2A is a flow chart illustrating a method performed by a network node, in accordance with some embodiments of the present disclosure.

[0074] The network node may comprise: a link aggregation group (LAG) module, an internet

protocol flow information export (IPFIX) module, and a statistics module.

[0075] As shown in FIG. 2A, the method 200 may comprise: a step S202, obtaining first information about at least one internet protocol (IP) flow, by the LAG module from the IPFIX module; a step S204, determining second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information, by the LAG module; a step S206, obtaining third information about at least one LAG member port, by the LAG module from the statistics module; and a step S208, selecting a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information, by the LAG module.

[0076] According to embodiments of the present disclosure, an improved manner for selecting LAG port for IP flow may be provided. Particularly, a LAG port may be selected for IP flow dynamically, based on information about the LAG port and/or the IP flow.

[0077] FIG. 2B is a flow chart illustrating a further step of the method in FIG. 2A, in accordance with some embodiments of the present disclosure.

[0078] The network node may further comprise an access control list, ACL, module. As shown in FIG. 2B, the method may further comprise: a step S210, sending the selected port, by the LAG module to the ACL module, to update an egress ACL.

[0079] According to embodiments of the present disclosure, only the egress ACL is updated. The egress ACL don't interrupt the original forwarding calculation of flow on ingress. The forwarding decision of routing/switching is not impacted. The encapsulation of outgoing traffic is also not impacted.

[0080] In embodiments of the present disclosure, the first information may comprise at least one of: IP tuples, a source port, a destination port, a packet number, or bytes for the at least one IP flow.

[0081] In embodiments of the present disclosure, the third information comprises: a status of congestion and/or bandwidth utilization on each port of the at least one LAG member port.

[0082] According to embodiments of the present disclosure, a congestion status on LAG member port in some scenario may be eliminated or at least reduced.

[0083] Further, according to embodiments of the present disclosure, the traffic loss on egress of LAG member port may be avoided. The bandwidth utilization of LAG may be improved. Automatically adjustment without manual operation and interference may be achieved.

[0084] In embodiments of the present disclosure, the status of congestion and/or bandwidth utilization may be obtained, based on a counter and/or a rate on each port of the at least one LAG member port.

[0085] In embodiments of the present disclosure, a port with less congestion and/or less bandwidth utilization may be selected for the at least one IP flow with higher rate.

[0086] In embodiments of the present disclosure, a port with a bandwidth utilization less than a threshold may be selected for the at least one IP flow.

[0087] In embodiments of the present disclosure, a free port may be selected for the at least one IP flow.

[0088] In embodiments of the present disclosure, the network node may comprise a switcher or a

router.

[0089] FIG. 3 is a schematic showing units for the exemplary apparatus for a network node, according to embodiments of the present disclosure.

[0090] As shown in FIG. 3, the apparatus 300 for the network node may comprise: a LAG module 302, an IPFIX module 304, and a statistics module 306. The LAG module 302 may be configured to: obtain first information about at least one internet protocol (IP) flow, from the IPFIX module 304; determine second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information; obtain third information about at least one LAG member port, from the statistics module 306; and select a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information.

[0091] Further, the apparatus 300 for the network node may further comprise: an ACL module 308. The LAG module 302 may be further configured to send the selected port to the ACL module 308 to update an egress ACL.

[0092] In embodiments of the present disclosure, the apparatus 300 may be operative to perform the method according to any of the above embodiments, such as these shown in FIG. 2A, 2B.

[0093] The term 'module' may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, units, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

[0094] With these modules, the apparatus may not need a fixed processor or memory, any kind of computing resource and storage resource may be arranged from at least one network node/device/entity/apparatus relating to the communication system. The virtualization technology and network computing technology (e.g., cloud computing) may be further introduced, so as to improve the usage efficiency of the network resources and the flexibility of the network.

[0095] The techniques described herein may be implemented by various means so that an apparatus implementing one or more functions of a corresponding apparatus described with an embodiment comprises not only prior art means, but also means for implementing the one or more functions of the corresponding apparatus described with the embodiment and it may comprise separate means for each separate function, or means that may be configured to perform two or more functions. For example, these techniques may be implemented in hardware (one or more apparatuses), firmware (one or more apparatuses), software (one or more modules/units), or combinations thereof. For a firmware or software, implementation may be made through modules (e.g., procedures, functions, and so on) that perform the functions described herein.

[0096] Particularly, these function modules may be implemented either as a network element on a dedicated hardware, as a software instance running on a dedicated hardware, or as a virtualized function instantiated on an appropriate platform, e.g., on a cloud infrastructure.

[0097] Embodiments herein afford many advantages. According to embodiments of the present disclosure, an improved manner for selecting LAG port for IP flow may be provided.

[0098] Particularly, a LAG port may be selected for IP flow dynamically, based on information about the LAG port and/or the IP flow. Therefore, a congestion status on LAG member port in some scenario may be eliminated or at least reduced.

[0099] Further, according to embodiments of the present disclosure, the traffic loss on egress of LAG member port may be avoided. The bandwidth utilization of LAG may be improved. Automatically adjustment without manual operation and interference may be achieved.

[00100] IPFIX is a general-purpose protocol that collects information from packets that travel into or out of an IPFIX device. The information that IPFIX samples can be defined, and that information may be sent to an external application for analysis.

[00101] In embodiments of the present disclosure, IPFIX may be applied to collect flows information including packets, bytes, IP tuples on egress of LAG member port. Considering the counters (for passed data and/or for dropped data) and congestion status of LAG member port, embodiments of the present disclosure download egress ACL which are generated by IPFIX flows causing the LAG member congestion, so as to redirect these IPFIX flows to free LAG member port. The congestion on LAG member port can be avoided, and the other free LAG member port can be used effectively.

[00102] Particularly, the forwarding decision of routing/switching is not impacted. The encapsulation of outgoing traffic is also not impacted.

[00103] According to embodiments of the present disclosure, IPFIX protocol is applied to collect information on egress of LAG/LAG member port on real time. Further, flows information is collected and the rate of flows is calculated. Then, the mapping tables of flows to the egress LAG member port may be created/maintained dynamically and in time. Flows with high rate on egress LAG member port may be considered and the egress ACL may be updated to change the destination port from congested port to the other port.

[00104] According to detailed embodiments, the IPFIX, ACL, Statistics and LAG may be the different modules in whole system.

[00105] The IPFIX can be applied on LAG or LAG port with indicated sample rate, and pre-defined templates or user-define templates.

[00106] Generally, the IPFIX metering and IPFIX exporter are implemented on the router or the switcher. The packets of flow will be sampled in chipset, and information of flow will be collected and integrated into templates of IPFIX from packets. Finally, the IPFIX protocol packets with format of templates will be sent out to IPFIX collector for analysis.

[00107] In these detailed embodiments, the information of flows IPFIX collected will be sent to LAG modules in order to get the features including IP tuples of flows and calculated rate of flows.

[00108] The statistics module broadcasts the counters and total rate of LAG number ports, the counters (such as for dropped data) and rate can be used to indicate the status of congestion and bandwidth utilization of LAG member ports. That is, it is used for detecting the congestion drop on LAG member port.

[00109] ACL modules can set the egress ACL entries into chipset to update a destination port of the specific flows.

[00110] FIG. 4 is a diagram showing the improved procedure of packets forwarding to LAG, according to embodiments of the present disclosure.

[00111] FIG. 4 shows the pipeline proposed by embodiments of the present disclosure. The basic procedure is substantially the same as the procedure shown in FIG. 1B.

[00112] After forwarding by routing table, the destination of LAG member port will be got by packet hashing with keys in fields of packet. The bolded and underlined block is egress ACL, which is used to change the destination of flows. The upper layer application will download the ACL rules into the egress ACL module to update the destination of the specific flow.

[00113] FIG. 5 is a function diagram illustrating further detailed embodiments of the present disclosure.

[00114] As shown in FIG.5, in the high-level software architecture, the routine procedure of this solution includes below steps:

[00115] In step (1), after applying the IPFIX on the whole LAG or LAG member ports, the packets sent out from LAG or LAG member ports will be sampled and punted to CPU (central processing unit) from the chipset.

[00116] In step (2), the callback of SDK will be called when sampled packets arrived on internal CPU port connected to the switching chipset. The callback will send the packets IPFIX packets processing module.

[00117] In step (3), after processing of original packets, the IP tuples, source port, destination port, packet number and bytes for specific flows will be sent to the IPFIX module for further processing.

[00118] In step (4), IPFIX module will sent the information of flows subscribed by the LAG module to the LAG module.

[00119] In step (5), the statistics module broadcasts the counters and rate of LAG number ports. The counters (such as for dropped data) and rate can be used to indicate the status of congestion and bandwidth utilization of LAG member ports.

[00120] In step (6), the LAG module will calculate which flows should be updated on egress ACL, when the congestion of LAG member ports happens according to the counters from statistics module. LAG module sends such event to models ACL to request downloading the egress ACL into the chipset.

[00121] In step (7), the ACL module will download the configuration to the configuration orchestration module.

[00122] In step (8), the configuration orchestration module will download egress ACL entries into SDK (software development kit).

[00123] In step (9), the SDK will install the egress ACL entries into the related registries of the chipsets.

[00124] FIG. 6 is a diagram showing a routine operation procedure in LAG module, according to embodiments of the present disclosure.

[00125] As shown in FIG. 6, there are 3 main threads in LAG module according to embodiments of the present disclosure: 1. collecting statistics of LAG number port; 2. collecting flow information on LAG number port; 3. Congestion checking and ACL generation for load balance between LAG number

ports.

[00126] In these embodiments, collecting the statistics of LAG number port will be periodically operated in order to check the real-time bandwidth utilization of LAG member ports.

[00127] The flow info including sample rate, interval of sample and cache, packet length, packet number, IP tuples, source port, destination port, etc. will be collected from IPFIX and used to calculate the rate of each flow on LAG number ports.

[00128] The main routine is periodically checking the bandwidth utilization and congestion status of LAG member port. When congestion did happen, or the bandwidth utilization of LAG member port reach a predetermined threshold, such as 90% of port line rate, the main routine tries to download ACL to move the parts of flow from original (congested) LAG member port to a less congested or free LAG member port.

[00129] Below, processing about how to calculate the bandwidth of flow with IPFIX will be further illustrated.

[00130] With applying IPFIX on egress of LAG member port, below data can be collected to differentiate traffic and calculate the speed of flows.

Flow ID	**IP Protocol**	**Source IP address**	**Destination IP address**	**Source port**	**Destination port**	**Packet length**	**Input interface**	**Flow Count**
1	UDP	167.1.2.3	162.1.2.6	20	30	128	1/1	2000
2	TCP	167.1.3.1	162.1.2.10	10	20	64	1/2	20000
3	TCP	167.1.6.1	163.1.7.1	21	61	1024	1/1	15000
6	UDP	20.1.20.1	42.2.6.70	20	2021	128	1/2	120
7	TCP	23.2.6.7	26.7.2.6	2000	2000	256	1/1	600
8	TCP	23.2.6.7	26.7.2.6	2000	2001	128	1/1	10000
9	TCP	23.2.6.7	26.7.2.6	2000	2002	3072	1/1	200000
10	UDP	16.16.2.1	16.17.3.1	3000	3001	1024	1/2	6000
...								

FCS: Frame Check (Checking) Sequence

SFD: Start Of Frame Delimiter

[00131] The rules including source IP, destination IP, source port and destination port are used as features of each flow. The speed of each flow can be calculated through blow formula with these data.

[00132] Speed of flow = (Preamble (7) + SFD (1) + Layer2 header (14) + <IP packet length> + FCS

(4) + interframe gap (12)) * Calculation interval *(delta flow count) * 8/IPFIX sample interval.

[00133] Take flow id 3(TCP, 167.1.6.1, 163.1.7.1, 21, 61) for example, the IPFIX sample interval is 1:3, Calculation interval is 5s and the delta flow count between the two calculation intervals is 1500.

[00134] The rate of the flow is (7+1+14+1024+4+12) * 5 * 1500 * 8 / (1/3) = 191160000 bps (bits per second) = 191Mbps.

[00135] Below, processing about way of setting thresholds for load balance will be further illustrated.

[00136] FIG. 7 is a diagram showing a predetermined threshold for bandwidth utilization of LAG member port, according to embodiments of the disclosure.

[00137] As shown in FIG. 7, two threshold values are designed, one is for threshold limit, the other is for threshold warning. When the bandwidth utilization of LAG member port reach threshold limit, the load balance will happen. The flows with high speed are selected and redirected to other free LAG member port. The bandwidth needed by the leftover flows will be lower than the threshold warning.

[00138] For example, one LAG has 2 10G(bps) ports. The threshold limit and threshold warning are 80% and 60% of LAG member port bandwidth. Three flows, speeds of which are 2Gbps, 2Gbps and 4Gbps, are forwarded to LAG member port 1. The load balance happens since 80% of bandwidth of LAG member port 1 are occupied. Then, the flow with 4G is selected and redirected to LAG member port 2. After that, new flow with 3Gbps is also forwarded to LAG member port 1. It will not trigger the load balance again.

[00139] FIG. 8 is a block diagram showing an exemplary apparatus for a network node, which is suitable for perform the method according to embodiments of the disclosure.

[00140] As shown in FIG. 8, an apparatus 300 for a network node in a communication network may comprise: a processor 801; and a memory 802. The memory may contain instructions executable by the processor. The apparatus for the network node may be operative for: obtaining first information about at least one internet protocol (IP) flow; determining second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information; obtaining third information about at least one LAG member port; and selecting a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information. Further, the third information may include a status of congestion and/or bandwidth utilization on each port of the at least one LAG member port.

[00141] In embodiments of the present disclosure, the apparatus 300 is further operative to perform the method according to any of the above embodiments, such as these shown in FIG. 2A, 2B, 4, 5, 6.

[00142] The processors 801 may be any kind of processing component, such as one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The memories 802 may be any kind of storage component, such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc.

[00143] FIG. 9 is a block diagram showing an apparatus/computer readable storage medium, according to embodiments of the present disclosure.

[00144] As shown in FIG. 9, the computer-readable storage medium 900, or any other kind of

product, storing instructions 901 which when executed by at least one processor, cause the at least one processor to perform the method according to any one of the above embodiments, such as these shown in FIG. 2A, 2B, 4, 5, 6.

[00145] In addition, the present disclosure may also provide a carrier containing the computer program as mentioned above, the carrier is one of an electronic signal, optical signal, radio signal, or computer readable storage medium. The computer readable storage medium can be, for example, an optical compact disk or an electronic memory device like a RAM (random access memory), a ROM (read only memory), Flash memory, magnetic tape, CD-ROM, DVD, Blue-ray disc and the like.

[00146] FIG. 10 shows an example of a communication system 1000 in accordance with some embodiments.

[00147] In the example, the communication system 1000 includes a telecommunication network 1002 that includes an access network 1004, such as a radio access network (RAN), and a core network 1006, which includes one or more core network nodes 1008. The access network 1004 includes one or more access network nodes, such as network nodes 1010a and 1010b (one or more of which may be generally referred to as network nodes 1010), or any other similar 3rd Generation Partnership Project (3GPP) access node or non-3GPP access point. The network nodes 1010 facilitate direct or indirect connection of user equipment (UE), such as by connecting UEs 1012a, 1012b, 1012c, and 1012d (one or more of which may be generally referred to as UEs 1012) to the core network 1006 over one or more wireless connections.

[00148] Example wireless communications over a wireless connection include transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information without the use of wires, cables, or other material conductors. Moreover, in different embodiments, the communication system 1000 may include any number of wired or wireless networks, network nodes, UEs, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections. The communication system 1000 may include and/or interface with any type of communication, telecommunication, data, cellular, radio network, and/or other similar type of system.

[00149] The UEs 1012 may be any of a wide variety of communication devices, including wireless devices arranged, configured, and/or operable to communicate wirelessly with the network nodes 1010 and other communication devices. Similarly, the network nodes 1010 are arranged, capable, configured, and/or operable to communicate directly or indirectly with the UEs 1012 and/or with other network nodes or equipment in the telecommunication network 1002 to enable and/or provide network access, such as wireless network access, and/or to perform other functions, such as administration in the telecommunication network 1002.

[00150] In the depicted example, the core network 1006 connects the network nodes 1010 to one or more hosts, such as host 1016. These connections may be direct or indirect via one or more intermediary networks or devices. In other examples, network nodes may be directly coupled to hosts. The core network 1006 includes one more core network nodes (e.g., core network node 1008) that are structured with hardware and software components. Features of these components may be substantially

similar to those described with respect to the UEs, network nodes, and/or hosts, such that the descriptions thereof are generally applicable to the corresponding components of the core network node 1008. Example core network nodes include functions of one or more of a Mobile Switching Center (MSC), Mobility Management Entity (MME), Home Subscriber Server (HSS), Access and Mobility Management Function (AMF), Session Management Function (SMF), Authentication Server Function (AUSF), Subscription Identifier De-concealing function (SIDF), Unified Data Management (UDM), Security Edge Protection Proxy (SEPP), Network Exposure Function (NEF), and/or a User Plane Function (UPF).

[00151] The host 1016 may be under the ownership or control of a service provider other than an operator or provider of the access network 1004 and/or the telecommunication network 1002, and may be operated by the service provider or on behalf of the service provider. The host 1016 may host a variety of applications to provide one or more service. Examples of such applications include live and pre-recorded audio/video content, data collection services such as retrieving and compiling data on various ambient conditions detected by a plurality of UEs, analytics functionality, social media, functions for controlling or otherwise interacting with remote devices, functions for an alarm and surveillance center, or any other such function performed by a server.

[00152] As a whole, the communication system 1000 of FIG. 10 enables connectivity between the UEs, network nodes, and hosts. In that sense, the communication system may be configured to operate according to predefined rules or procedures, such as specific standards that include, but are not limited to: Global System for Mobile Communications (GSM); Universal Mobile Telecommunications System (UMTS); Long Term Evolution (LTE), and/or other suitable 2G, 3G, 4G, 5G standards, or any applicable future generation standard (e.g., 6G); wireless local area network (WLAN) standards, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards (WiFi); and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave, Near Field Communication (NFC) ZigBee, LiFi, and/or any low-power wide-area network (LPWAN) standards such as LoRa and Sigfox.

[00153] In some examples, the telecommunication network 1002 is a cellular network that implements 3GPP standardized features. Accordingly, the telecommunications network 1002 may support network slicing to provide different logical networks to different devices that are connected to the telecommunication network 1002. For example, the telecommunications network 1002 may provide Ultra Reliable Low Latency Communication (URLLC) services to some UEs, while providing Enhanced Mobile Broadband (eMBB) services to other UEs, and/or Massive Machine Type Communication (mMTC)/Massive IoT services to yet further UEs.

[00154] In some examples, the UEs 1012 are configured to transmit and/or receive information without direct human interaction. For instance, a UE may be designed to transmit information to the access network 1004 on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the access network 1004. Additionally, a UE may be configured for operating in single- or multi-RAT or multi-standard mode. For example, a UE may operate with any one or combination of Wi-Fi, NR (New Radio) and LTE, i.e. being configured for multi-radio dual

connectivity (MR-DC), such as E-UTRAN (Evolved-UMTS Terrestrial Radio Access Network) New Radio – Dual Connectivity (EN-DC).

[00155] In the example, the hub 1014 communicates with the access network 1004 to facilitate indirect communication between one or more UEs (e.g., UE 1012c and/or 1012d) and network nodes (e.g., network node 1010b). In some examples, the hub 1014 may be a controller, router, content source and analytics, or any of the other communication devices described herein regarding UEs. For example, the hub 1014 may be a broadband router enabling access to the core network 1006 for the UEs. As another example, the hub 1014 may be a controller that sends commands or instructions to one or more actuators in the UEs. Commands or instructions may be received from the UEs, network nodes 1010, or by executable code, script, process, or other instructions in the hub 1014. As another example, the hub 1014 may be a data collector that acts as temporary storage for UE data and, in some embodiments, may perform analysis or other processing of the data. As another example, the hub 1014 may be a content source. For example, for a UE that is a VR headset, display, loudspeaker or other media delivery device, the hub 1014 may retrieve VR assets, video, audio, or other media or data related to sensory information via a network node, which the hub 1014 then provides to the UE either directly, after performing local processing, and/or after adding additional local content. In still another example, the hub 1014 acts as a proxy server or orchestrator for the UEs, in particular in if one or more of the UEs are low energy IoT devices.

[00156] The hub 1014 may have a constant/persistent or intermittent connection to the network node 1010b. The hub 1014 may also allow for a different communication scheme and/or schedule between the hub 1014 and UEs (e.g., UE 1012c and/or 1012d), and between the hub 1014 and the core network 1006. In other examples, the hub 1014 is connected to the core network 1006 and/or one or more UEs via a wired connection. Moreover, the hub 1014 may be configured to connect to an M2M service provider over the access network 1004 and/or to another UE over a direct connection. In some scenarios, UEs may establish a wireless connection with the network nodes 1010 while still connected via the hub 1014 via a wired or wireless connection. In some embodiments, the hub 1014 may be a dedicated hub – that is, a hub whose primary function is to route communications to/from the UEs from/to the network node 1010b. In other embodiments, the hub 1014 may be a non-dedicated hub – that is, a device which is capable of operating to route communications between the UEs and network node 1010b, but which is additionally capable of operating as a communication start and/or end point for certain data channels.

[00157] FIG. 11 shows a UE 1100 in accordance with some embodiments. As used herein, a UE refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other UEs. Examples of a UE include, but are not limited to, a smart phone, mobile phone, cell phone, voice over IP (VoIP) phone, wireless local loop phone, desktop computer, personal digital assistant (PDA), wireless cameras, gaming console or device, music storage device, playback appliance, wearable terminal device, wireless endpoint, mobile station, tablet, laptop, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), smart device, wireless customer-premise equipment (CPE), vehicle-mounted or vehicle embedded/integrated wireless device, etc.

Other examples include any UE identified by the 3rd Generation Partnership Project (3GPP), including a narrow band internet of things (NB-IoT) UE, a machine type communication (MTC) UE, and/or an enhanced MTC (eMTC) UE.

[00158] A UE may support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, Dedicated Short-Range Communication (DSRC), vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), or vehicle-to-everything (V2X). In other examples, a UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (e.g., a smart sprinkler controller). Alternatively, a UE may represent a device that is not intended for sale to, or operation by, an end user but which may be associated with or operated for the benefit of a user (e.g., a smart power meter).

[00159] The UE 1100 includes processing circuitry 1102 that is operatively coupled via a bus 1104 to an input/output interface 1106, a power source 1108, a memory 1110, a communication interface 1112, and/or any other component, or any combination thereof. Certain UEs may utilize all or a subset of the components shown in FIG. 11. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

[00160] The processing circuitry 1102 is configured to process instructions and data and may be configured to implement any sequential state machine operative to execute instructions stored as machine-readable computer programs in the memory 1110. The processing circuitry 1102 may be implemented as one or more hardware-implemented state machines (e.g., in discrete logic, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), etc.); programmable logic together with appropriate firmware; one or more stored computer programs, general-purpose processors, such as a microprocessor or digital signal processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 1102 may include multiple central processing units (CPUs).

[00161] In the example, the input/output interface 1106 may be configured to provide an interface or interfaces to an input device, output device, or one or more input and/or output devices. Examples of an output device include a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. An input device may allow a user to capture information into the UE 1100. Examples of an input device include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, a biometric sensor, etc., or any combination thereof. An output device may use the same type of interface port as an input

device. For example, a Universal Serial Bus (USB) port may be used to provide an input device and an output device.

[00162] In some embodiments, the power source 1108 is structured as a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic device, or power cell, may be used. The power source 1108 may further include power circuitry for delivering power from the power source 1108 itself, and/or an external power source, to the various parts of the UE 1100 via input circuitry or an interface such as an electrical power cable. Delivering power may be, for example, for charging of the power source 1108. Power circuitry may perform any formatting, converting, or other modification to the power from the power source 1108 to make the power suitable for the respective components of the UE 1100 to which power is supplied.

[00163] The memory 1110 may be or be configured to include memory such as random access memory (RAM), read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, hard disks, removable cartridges, flash drives, and so forth. In one example, the memory 1110 includes one or more application programs 1114, such as an operating system, web browser application, a widget, gadget engine, or other application, and corresponding data 1116. The memory 1110 may store, for use by the UE 1100, any of a variety of various operating systems or combinations of operating systems.

[00164] The memory 1110 may be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), flash memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, high-density digital versatile disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, holographic digital data storage (HDDS) optical disc drive, external mini-dual in-line memory module (DIMM), synchronous dynamic random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as tamper resistant module in the form of a universal integrated circuit card (UICC) including one or more subscriber identity modules (SIMs), such as a USIM and/or ISIM, other memory, or any combination thereof. The UICC may for example be an embedded UICC (eUICC), integrated UICC (iUICC) or a removable UICC commonly known as 'SIM card.' The memory 1110 may allow the UE 1100 to access instructions, application programs and the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied as or in the memory 1110, which may be or comprise a device-readable storage medium.

[00165] The processing circuitry 1102 may be configured to communicate with an access network or other network using the communication interface 1112. The communication interface 1112 may comprise one or more communication subsystems and may include or be communicatively coupled to an antenna 1122. The communication interface 1112 may include one or more transceivers used to communicate, such as by communicating with one or more remote transceivers of another device capable of wireless communication (e.g., another UE or a network node in an access network). Each transceiver may include a transmitter 1118 and/or a receiver 1120 appropriate to provide network

communications (e.g., optical, electrical, frequency allocations, and so forth). Moreover, the transmitter 1118 and receiver 1120 may be coupled to one or more antennas (e.g., antenna 1122) and may share circuit components, software or firmware, or alternatively be implemented separately.

[00166] In the illustrated embodiment, communication functions of the communication interface 1112 may include cellular communication, Wi-Fi communication, LPWAN communication, data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. Communications may be implemented in according to one or more communication protocols and/or standards, such as IEEE 802.11, Code Division Multiplexing Access (CDMA), Wideband Code Division Multiple Access (WCDMA), GSM, LTE, New Radio (NR), UMTS, WiMax, Ethernet, transmission control protocol/internet protocol (TCP/IP), synchronous optical networking (SONET), Asynchronous Transfer Mode (ATM), QUIC, Hypertext Transfer Protocol (HTTP), and so forth.

[00167] Regardless of the type of sensor, a UE may provide an output of data captured by its sensors, through its communication interface 1112, via a wireless connection to a network node. Data captured by sensors of a UE can be communicated through a wireless connection to a network node via another UE. The output may be periodic (e.g., once every 15 minutes if it reports the sensed temperature), random (e.g., to even out the load from reporting from several sensors), in response to a triggering event (e.g., when moisture is detected an alert is sent), in response to a request (e.g., a user initiated request), or a continuous stream (e.g., a live video feed of a patient).

[00168] As another example, a UE comprises an actuator, a motor, or a switch, related to a communication interface configured to receive wireless input from a network node via a wireless connection. In response to the received wireless input the states of the actuator, the motor, or the switch may change. For example, the UE may comprise a motor that adjusts the control surfaces or rotors of a drone in flight according to the received input or to a robotic arm performing a medical procedure according to the received input.

[00169] A UE, when in the form of an Internet of Things (IoT) device, may be a device for use in one or more application domains, these domains comprising, but not limited to, city wearable technology, extended industrial application and healthcare. Non-limiting examples of such an IoT device are a device which is or which is embedded in: a connected refrigerator or freezer, a TV, a connected lighting device, an electricity meter, a robot vacuum cleaner, a voice controlled smart speaker, a home security camera, a motion detector, a thermostat, a smoke detector, a door/window sensor, a flood/moisture sensor, an electrical door lock, a connected doorbell, an air conditioning system like a heat pump, an autonomous vehicle, a surveillance system, a weather monitoring device, a vehicle parking monitoring device, an electric vehicle charging station, a smart watch, a fitness tracker, a head-mounted display for Augmented Reality (AR) or Virtual Reality (VR), a wearable for tactile augmentation or sensory enhancement, a water sprinkler, an animal- or item-tracking device, a sensor for monitoring a plant or animal, an industrial robot, an Unmanned Aerial Vehicle (UAV), and

any kind of medical device, like a heart rate monitor or a remote controlled surgical robot. A UE in the form of an IoT device comprises circuitry and/or software in dependence of the intended application of the IoT device in addition to other components as described in relation to the UE 1100 shown in FIG. 11.

[00170] As yet another specific example, in an IoT scenario, a UE may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another UE and/or a network node. The UE may in this case be an M2M device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the UE may implement the 3GPP NB-IoT standard. In other scenarios, a UE may represent a vehicle, such as a car, a bus, a truck, a ship and an airplane, or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation.

[00171] In practice, any number of UEs may be used together with respect to a single use case. For example, a first UE might be or be integrated in a drone and provide the drone's speed information (obtained through a speed sensor) to a second UE that is a remote controller operating the drone. When the user makes changes from the remote controller, the first UE may adjust the throttle on the drone (e.g. by controlling an actuator) to increase or decrease the drone's speed. The first and/or the second UE can also include more than one of the functionalities described above. For example, a UE might comprise the sensor and the actuator, and handle communication of data for both the speed sensor and the actuators.

[00172] FIG. 12 shows a network node 1200 in accordance with some embodiments. As used herein, network node refers to equipment capable, configured, arranged and/or operable to communicate directly or indirectly with a UE and/or with other network nodes or equipment, in a telecommunication network. Examples of network nodes include, but are not limited to, access points (APs) (e.g., radio access points), base stations (BSs) (e.g., radio base stations, Node Bs, evolved Node Bs (eNBs) and NR NodeBs (gNBs)).

[00173] Base stations may be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and so, depending on the provided amount of coverage, may be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station may be a relay node or a relay donor node controlling a relay. A network node may also include one or more (or all) parts of a distributed radio base station such as centralized digital units and/or remote radio units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such remote radio units may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station may also be referred to as nodes in a distributed antenna system (DAS).

[00174] Other examples of network nodes include multiple transmission point (multi-TRP) 5G access nodes, multi-standard radio (MSR) equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, multi-cell/multicast coordination entities (MCEs), Operation and Maintenance (O&M) nodes, Operations Support System (OSS) nodes, Self-Organizing Network

(SON) nodes, positioning nodes (e.g., Evolved Serving Mobile Location Centers (E-SMLCs)), and/or Minimization of Drive Tests (MDTs).

[00175] The network node 1200 includes a processing circuitry 1202, a memory 1204, a communication interface 1206, and a power source 1208. The network node 1200 may be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which the network node 1200 comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components may be shared among several network nodes. For example, a single RNC may control multiple NodeBs. In such a scenario, each unique NodeB and RNC pair, may in some instances be considered a single separate network node. In some embodiments, the network node 1200 may be configured to support multiple radio access technologies (RATs). In such embodiments, some components may be duplicated (e.g., separate memory 1204 for different RATs) and some components may be reused (e.g., a same antenna 1210 may be shared by different RATs). The network node 1200 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 1200, for example GSM, WCDMA, LTE, NR, WiFi, Zigbee, Z-wave, LoRaWAN, Radio Frequency Identification (RFID) or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within network node 1200.

[00176] The processing circuitry 1202 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node 1200 components, such as the memory 1204, to provide network node 1200 functionality.

[00177] In some embodiments, the processing circuitry 1202 includes a system on a chip (SOC). In some embodiments, the processing circuitry 1202 includes one or more of radio frequency (RF) transceiver circuitry 1212 and baseband processing circuitry 1214. In some embodiments, the radio frequency (RF) transceiver circuitry 1212 and the baseband processing circuitry 1214 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry 1212 and baseband processing circuitry 1214 may be on the same chip or set of chips, boards, or units.

[00178] The memory 1204 may comprise any form of volatile or non-volatile computer-readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device-readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by the processing circuitry 1202. The memory 1204 may store

any suitable instructions, data, or information, including a computer program, software, an application including one or more of logic, rules, code, tables, and/or other instructions capable of being executed by the processing circuitry 1202 and utilized by the network node 1200. The memory 1204 may be used to store any calculations made by the processing circuitry 1202 and/or any data received via the communication interface 1206. In some embodiments, the processing circuitry 1202 and memory 1204 is integrated.

[00179] The communication interface 1206 is used in wired or wireless communication of signaling and/or data between a network node, access network, and/or UE. As illustrated, the communication interface 1206 comprises port(s)/terminal(s) 1216 to send and receive data, for example to and from a network over a wired connection. The communication interface 1206 also includes radio front-end circuitry 1218 that may be coupled to, or in certain embodiments a part of, the antenna 1210. Radio front-end circuitry 1218 comprises filters 1220 and amplifiers 1222. The radio front-end circuitry 1218 may be connected to an antenna 1210 and processing circuitry 1202. The radio front-end circuitry may be configured to condition signals communicated between antenna 1210 and processing circuitry 1202. The radio front-end circuitry 1218 may receive digital data that is to be sent out to other network nodes or UEs via a wireless connection. The radio front-end circuitry 1218 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 1220 and/or amplifiers 1222. The radio signal may then be transmitted via the antenna 1210. Similarly, when receiving data, the antenna 1210 may collect radio signals which are then converted into digital data by the radio front-end circuitry 1218. The digital data may be passed to the processing circuitry 1202. In other embodiments, the communication interface may comprise different components and/or different combinations of components.

[00180] In certain alternative embodiments, the network node 1200 does not include separate radio front-end circuitry 1218, instead, the processing circuitry 1202 includes radio front-end circuitry and is connected to the antenna 1210. Similarly, in some embodiments, all or some of the RF transceiver circuitry 1212 is part of the communication interface 1206. In still other embodiments, the communication interface 1206 includes one or more ports or terminals 1216, the radio front-end circuitry 1218, and the RF transceiver circuitry 1212, as part of a radio unit (not shown), and the communication interface 1206 communicates with the baseband processing circuitry 1214, which is part of a digital unit (not shown).

[00181] The antenna 1210 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. The antenna 1210 may be coupled to the radio front-end circuitry 1218 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In certain embodiments, the antenna 1210 is separate from the network node 1200 and connectable to the network node 1200 through an interface or port.

[00182] The antenna 1210, communication interface 1206, and/or the processing circuitry 1202 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by the network node. Any information, data and/or signals may be received from a UE, another network node and/or any other network equipment. Similarly, the antenna 1210, the

communication interface 1206, and/or the processing circuitry 1202 may be configured to perform any transmitting operations described herein as being performed by the network node. Any information, data and/or signals may be transmitted to a UE, another network node and/or any other network equipment.

[00183] The power source 1208 provides power to the various components of network node 1200 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). The power source 1208 may further comprise, or be coupled to, power management circuitry to supply the components of the network node 1200 with power for performing the functionality described herein. For example, the network node 1200 may be connectable to an external power source (e.g., the power grid, an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to power circuitry of the power source 1208. As a further example, the power source 1208 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry. The battery may provide backup power should the external power source fail.

[00184] Embodiments of the network node 1200 may include additional components beyond those shown in FIG. 12 for providing certain aspects of the network node's functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, the network node 1200 may include user interface equipment to allow input of information into the network node 1200 and to allow output of information from the network node 1200. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for the network node 1200.

[00185] FIG. 13 is a block diagram of a host 1300, which may be an embodiment of the host 1016 of FIG. 10, in accordance with various aspects described herein. As used herein, the host 1300 may be or comprise various combinations hardware and/or software, including a standalone server, a blade server, a cloud-implemented server, a distributed server, a virtual machine, container, or processing resources in a server farm. The host 1300 may provide one or more services to one or more UEs.

[00186] The host 1300 includes processing circuitry 1302 that is operatively coupled via a bus 1304 to an input/output interface 1306, a network interface 1308, a power source 1310, and a memory 1312. Other components may be included in other embodiments. Features of these components may be substantially similar to those described with respect to the devices of previous figures, such as Figures 11 and 12, such that the descriptions thereof are generally applicable to the corresponding components of host 1300.

[00187] The memory 1312 may include one or more computer programs including one or more host application programs 1314 and data 1316, which may include user data, e.g., data generated by a UE for the host 1300 or data generated by the host 1300 for a UE. Embodiments of the host 1300 may utilize only a subset or all of the components shown. The host application programs 1314 may be implemented in a container-based architecture and may provide support for video codecs (e.g., Versatile Video Coding (VVC), High Efficiency Video Coding (HEVC), Advanced Video Coding (AVC), MPEG, VP9) and audio codecs (e.g., FLAC, Advanced Audio Coding (AAC), MPEG, G.711),

including transcoding for multiple different classes, types, or implementations of UEs (e.g., handsets, desktop computers, wearable display systems, heads-up display systems). The host application programs 1314 may also provide for user authentication and licensing checks and may periodically report health, routes, and content availability to a central node, such as a device in or on the edge of a core network. Accordingly, the host 1300 may select and/or indicate a different host for over-the-top services for a UE. The host application programs 1314 may support various protocols, such as the HTTP Live Streaming (HLS) protocol, Real-Time Messaging Protocol (RTMP), Real-Time Streaming Protocol (RTSP), Dynamic Adaptive Streaming over HTTP (MPEG-DASH), etc.

[00188] FIG. 14 is a block diagram illustrating a virtualization environment 1400 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to any device described herein, or components thereof, and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components. Some or all of the functions described herein may be implemented as virtual components executed by one or more virtual machines (VMs) implemented in one or more virtual environments 1400 hosted by one or more of hardware nodes, such as a hardware computing device that operates as a network node, UE, core network node, or host. Further, in embodiments in which the virtual node does not require radio connectivity (e.g., a core network node or host), then the node may be entirely virtualized.

[00189] Applications 1402 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) are run in the virtualization environment Q400 to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein.

[00190] Hardware 1404 includes processing circuitry, memory that stores software and/or instructions executable by hardware processing circuitry, and/or other hardware devices as described herein, such as a network interface, input/output interface, and so forth. Software may be executed by the processing circuitry to instantiate one or more virtualization layers 1406 (also referred to as hypervisors or virtual machine monitors (VMMs)), provide VMs 1408a and 1408b (one or more of which may be generally referred to as VMs 1408), and/or perform any of the functions, features and/or benefits described in relation with some embodiments described herein. The virtualization layer 1406 may present a virtual operating platform that appears like networking hardware to the VMs 1408.

[00191] The VMs 1408 comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 1406. Different embodiments of the instance of a virtual appliance 1402 may be implemented on one or more of VMs 1408, and the implementations may be made in different ways. Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high volume server hardware, physical switches, and physical storage, which can be located in data centers, and customer premise equipment.

[00192] In the context of NFV, a VM 1408 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of the VMs 1408, and that part of hardware 1404 that executes that VM, be it hardware dedicated to that VM and/or hardware shared by that VM with others of the VMs, forms separate virtual network elements. Still in the context of NFV, a virtual network function is responsible for handling specific network functions that run in one or more VMs 1408 on top of the hardware 1404 and corresponds to the application 1402.

[00193] Hardware 1404 may be implemented in a standalone network node with generic or specific components. Hardware 1404 may implement some functions via virtualization. Alternatively, hardware 1404 may be part of a larger cluster of hardware (e.g. such as in a data center or CPE) where many hardware nodes work together and are managed via management and orchestration 1410, which, among others, oversees lifecycle management of applications 1402. In some embodiments, hardware 1404 is coupled to one or more radio units that each include one or more transmitters and one or more receivers that may be coupled to one or more antennas. Radio units may communicate directly with other hardware nodes via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station. In some embodiments, some signaling can be provided with the use of a control system 1412 which may alternatively be used for communication between hardware nodes and radio units.

[00194] FIG. 15 shows a communication diagram of a host 1502 communicating via a network node 1504 with a UE 1506 over a partially wireless connection in accordance with some embodiments. Example implementations, in accordance with various embodiments, of the UE (such as a UE 1012a of FIG. 10 and/or UE 1100 of FIG. 11), network node (such as network node 1010a of FIG. 10 and/or network node 1200 of FIG. 12), and host (such as host 1016 of FIG. 10 and/or host 1300 of FIG. 13) discussed in the preceding paragraphs will now be described with reference to FIG. 15.

[00195] Like host 1300, embodiments of host 1502 include hardware, such as a communication interface, processing circuitry, and memory. The host 1502 also includes software, which is stored in or accessible by the host 1502 and executable by the processing circuitry. The software includes a host application that may be operable to provide a service to a remote user, such as the UE 1506 connecting via an over-the-top (OTT) connection 1550 extending between the UE 1506 and host 1502. In providing the service to the remote user, a host application may provide user data which is transmitted using the OTT connection 1550.

[00196] The network node 1504 includes hardware enabling it to communicate with the host 1502 and UE 1506. The connection 1560 may be direct or pass through a core network (like core network 1006 of FIG. 10) and/or one or more other intermediate networks, such as one or more public, private, or hosted networks. For example, an intermediate network may be a backbone network or the Internet.

[00197] The UE 1506 includes hardware and software, which is stored in or accessible by UE 1506 and executable by the UE's processing circuitry. The software includes a client application, such as a web browser or operator-specific "app" that may be operable to provide a service to a human or non-

human user via UE 1506 with the support of the host 1502. In the host 1502, an executing host application may communicate with the executing client application via the OTT connection 1550 terminating at the UE 1506 and host 1502. In providing the service to the user, the UE's client application may receive request data from the host's host application and provide user data in response to the request data. The OTT connection 1550 may transfer both the request data and the user data. The UE's client application may interact with the user to generate the user data that it provides to the host application through the OTT connection 1550.

[00198] The OTT connection 1550 may extend via a connection 1560 between the host 1502 and the network node 1504 and via a wireless connection 1570 between the network node 1504 and the UE 1506 to provide the connection between the host 1502 and the UE 1506. The connection 1560 and wireless connection 1570, over which the OTT connection 1550 may be provided, have been drawn abstractly to illustrate the communication between the host 1502 and the UE 1506 via the network node 1504, without explicit reference to any intermediary devices and the precise routing of messages via these devices.

[00199] As an example of transmitting data via the OTT connection 1550, in step 1508, the host 1502 provides user data, which may be performed by executing a host application. In some embodiments, the user data is associated with a particular human user interacting with the UE 1506. In other embodiments, the user data is associated with a UE 1506 that shares data with the host 1502 without explicit human interaction. In step 1510, the host 1502 initiates a transmission carrying the user data towards the UE 1506. The host 1502 may initiate the transmission responsive to a request transmitted by the UE 1506. The request may be caused by human interaction with the UE 1506 or by operation of the client application executing on the UE 1506. The transmission may pass via the network node 1504, in accordance with the teachings of the embodiments described throughout this disclosure. Accordingly, in step 1512, the network node 1504 transmits to the UE 1506 the user data that was carried in the transmission that the host 1502 initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 1514, the UE 1506 receives the user data carried in the transmission, which may be performed by a client application executed on the UE 1506 associated with the host application executed by the host 1502.

[00200] In some examples, the UE 1506 executes a client application which provides user data to the host 1502. The user data may be provided in reaction or response to the data received from the host 1502. Accordingly, in step 1516, the UE 1506 may provide user data, which may be performed by executing the client application. In providing the user data, the client application may further consider user input received from the user via an input/output interface of the UE 1506. Regardless of the specific manner in which the user data was provided, the UE 1506 initiates, in step 1518, transmission of the user data towards the host 1502 via the network node 1504. In step 1520, in accordance with the teachings of the embodiments described throughout this disclosure, the network node 1504 receives user data from the UE 1506 and initiates transmission of the received user data towards the host 1502. In step 1522, the host 1502 receives the user data carried in the transmission initiated by the UE 1506.

[00201] One or more of the various embodiments improve the performance of OTT services provided to the UE 1506 using the OTT connection 1550, in which the wireless connection 1570 forms the last segment. According to embodiments of the present disclosure, an improved manner for selecting LAG port for IP flow may be provided. Particularly, a congestion status on LAG member port in some scenario may be eliminated or at least reduced. More precisely, the teachings of these embodiments may improve the performance, e.g., data rate, latency, power consumption, of the communication network, and thereby provide benefits such as reduced user waiting time, relaxed restriction on file size, improved content resolution, better responsiveness, extended battery lifetime.

[00202] In an example scenario, factory status information may be collected and analyzed by the host 1502. As another example, the host 1502 may process audio and video data which may have been retrieved from a UE for use in creating maps. As another example, the host 1502 may collect and analyze real-time data to assist in controlling vehicle congestion (e.g., controlling traffic lights). As another example, the host 1502 may store surveillance video uploaded by a UE. As another example, the host 1502 may store or control access to media content such as video, audio, VR or AR which it can broadcast, multicast or unicast to UEs. As other examples, the host 1502 may be used for energy pricing, remote control of non-time critical electrical load to balance power generation needs, location services, presentation services (such as compiling diagrams etc. from data collected from remote devices), or any other function of collecting, retrieving, storing, analyzing and/or transmitting data.

[00203] In some examples, a measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring the OTT connection 1550 between the host 1502 and UE 1506, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection may be implemented in software and hardware of the host 1502 and/or UE 1506. In some embodiments, sensors (not shown) may be deployed in or in association with other devices through which the OTT connection 1550 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software may compute or estimate the monitored quantities. The reconfiguring of the OTT connection 1550 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not directly alter the operation of the network node 1504. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling that facilitates measurements of throughput, propagation times, latency and the like, by the host 1502. The measurements may be implemented in that software causes messages to be transmitted, in particular empty or 'dummy' messages, using the OTT connection 1550 while monitoring propagation times, errors, etc.

[00204] Although the computing devices described herein (e.g., UEs, network nodes, hosts) may include the illustrated combination of hardware components, other embodiments may comprise computing devices with different combinations of components. It is to be understood that these computing devices may comprise any suitable combination of hardware and/or software needed to

perform the tasks, features, functions and methods disclosed herein. Determining, calculating, obtaining or similar operations described herein may be performed by processing circuitry, which may process information by, for example, converting the obtained information into other information, comparing the obtained information or converted information to information stored in the network node, and/or performing one or more operations based on the obtained information or converted information, and as a result of said processing making a determination. Moreover, while components are depicted as single boxes located within a larger box, or nested within multiple boxes, in practice, computing devices may comprise multiple different physical components that make up a single illustrated component, and functionality may be partitioned between separate components. For example, a communication interface may be configured to include any of the components described herein, and/or the functionality of the components may be partitioned between the processing circuitry and the communication interface. In another example, non-computationally intensive functions of any of such components may be implemented in software or firmware and computationally intensive functions may be implemented in hardware.

[00205] In certain embodiments, some or all of the functionality described herein may be provided by processing circuitry executing instructions stored on in memory, which in certain embodiments may be a computer program product in the form of a non-transitory computer-readable storage medium. In alternative embodiments, some or all of the functionality may be provided by the processing circuitry without executing instructions stored on a separate or discrete device-readable storage medium, such as in a hard-wired manner. In any of those particular embodiments, whether executing instructions stored on a non-transitory computer-readable storage medium or not, the processing circuitry can be configured to perform the described functionality. The benefits provided by such functionality are not limited to the processing circuitry alone or to other components of the computing device, but are enjoyed by the computing device as a whole, and/or by end users and a wireless network generally.

[00206] REFERENCE

[00207] B. Trammell and E. Boschi, "An introduction to IP flow information export (IPFIX)," in IEEE Communications Magazine, vol. 49, no. 4, pp. 89-95, April 2011, doi: 10.1109/MCOM.2011.5741152.

[00208] "IEEE Standard for Ethernet," in IEEE Std 802.3-2018 (Revision of IEEE Std 802.3-2015) , vol., no., pp.1-5600, 31 Aug. 2018, doi: 10.1109/IEEESTD.2018.8457469.

[00209] "IEEE Standard for Local and Metropolitan Area Networks--Link Aggregation," in IEEE Std 802.1AX-2020 (Revision of IEEE Std 802.1AX-2014) , vol., no., pp.1-333, 29 May 2020, doi: 10.1109/IEEESTD.2020.9105034.

CLAIMS

1. A method (200) performed by a network node, the network node comprising: a link aggregation group, LAG, module, an internet protocol flow information export, IPFIX, module, and a statistics module;

the method (200) comprises:

obtaining (S202) first information about at least one internet protocol, IP, flow, by the LAG module from the IPFIX module;

determining (S204) second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information, by the LAG module;

obtaining (S206) third information about at least one LAG member port, by the LAG module from the statistics module; and

selecting (S208) a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information, by the LAG module.

2. The method (200) according to claim 1,

wherein the network node further comprises an access control list, ACL, module;

the method (200) further comprises:

sending (S210) the selected port, by the LAG module to the ACL module, to update an egress ACL.

3. The method (200) according to claim 1 or 2,

wherein the first information comprises at least one of: IP tuples, a source port, a destination port, a packet number, or bytes for the at least one IP flow.

4. The method (200) according to any of claims 1 to 3,

wherein the third information comprises: a status of congestion and/or bandwidth utilization on each port of the at least one LAG member port.

5. The method (200) according to claim 4,

wherein the status of congestion and/or bandwidth utilization is obtained, based on a counter and/or a rate on each port of the at least one LAG member port.

6. The method (200) according to any of claims 1 to 5,

wherein a port with less congestion and/or less bandwidth utilization is selected for the at least one IP flow with higher rate.

7. The method (200) according to claim 6,

wherein a port with a bandwidth utilization less than a threshold is selected for the at least one IP

flow.

8. The method (200) according to claim 7,
wherein a free port is selected for the at least one IP flow.

9. The method (200) according to any of claims 1 to 8,
wherein the network node comprises a switcher or a router.

10. An apparatus (300) for a network node in a communication network, comprising: a LAG module (302), an IPFIX module (304), and a statistics module (306);
wherein the LAG module (302) is configured to:
obtain first information about at least one internet protocol, IP, flow, from the IPFIX module (304);
determine second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information;
obtain third information about at least one LAG member port, from the statistics module (306); and
select a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information.

11. The apparatus (300) according to claim 10, wherein the apparatus (300) is further operative to perform the method according to any of claims 2 to 9.

12. A computer-readable storage medium (900) storing instructions (901), which when executed by at least one processor, cause the at least one processor to perform the method according to any one of claims 1 to 9.

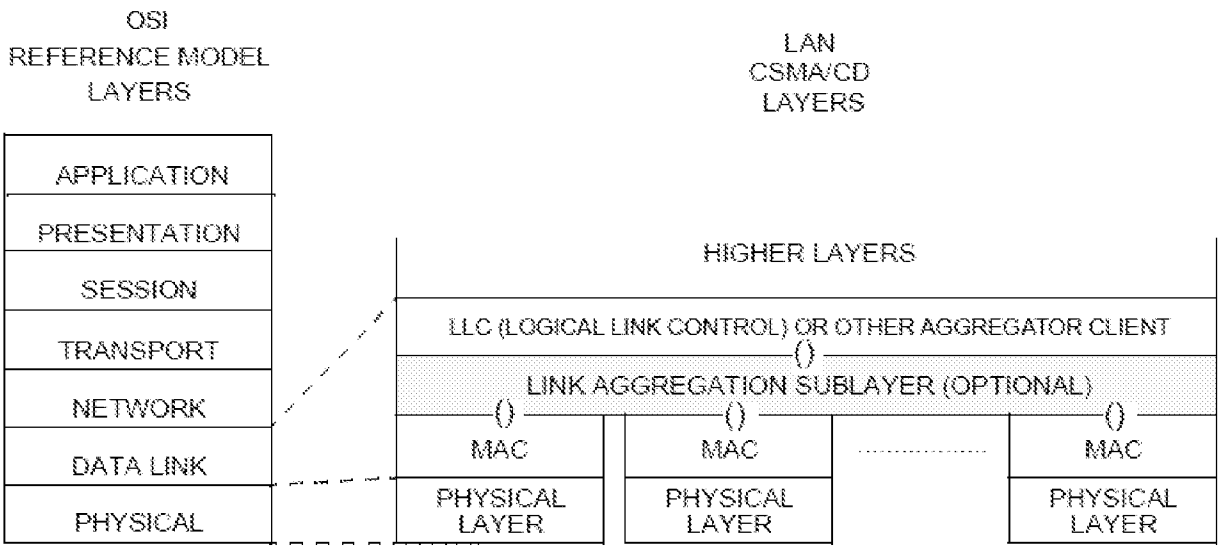
OSI
REFERENCE MODEL
LAYERS
APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL
LAN
CSMA/CD
LAYERS
HIGHER LAYERS
LLC (LOGICAL LINK CONTROL) OR OTHER AGGREGATOR CLIENT
LINK AGGREGATION SUBLAYER (OPTIONAL)
MAC
MAC
MAC
PHYSICAL LAYER
PHYSICAL LAYER
PHYSICAL LAYER

FIG. 1A

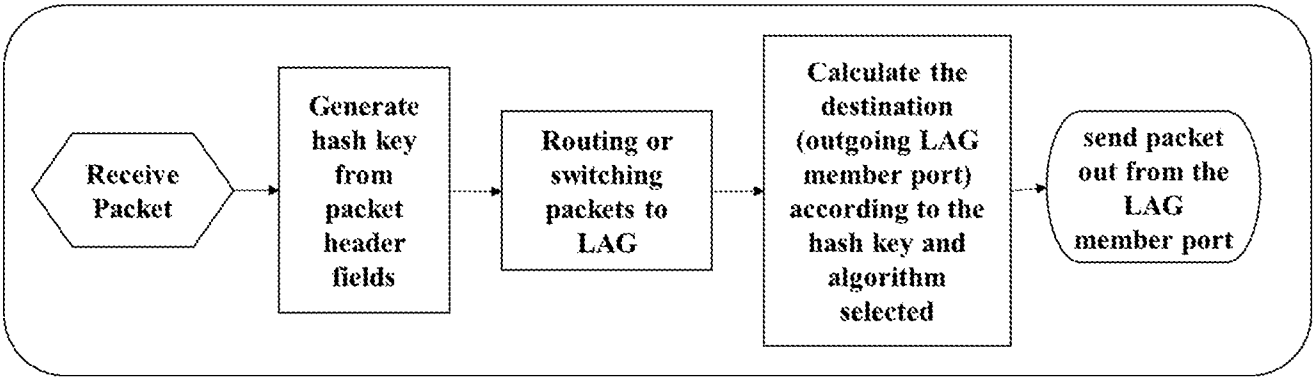
Receive Packet
Generate hash key from packet header fields
Routing or switching packets to LAG
Calculate the destination (outgoing LAG member port) according to the hash key and algorithm selected
send packet out from the LAG member port

FIG. 1B

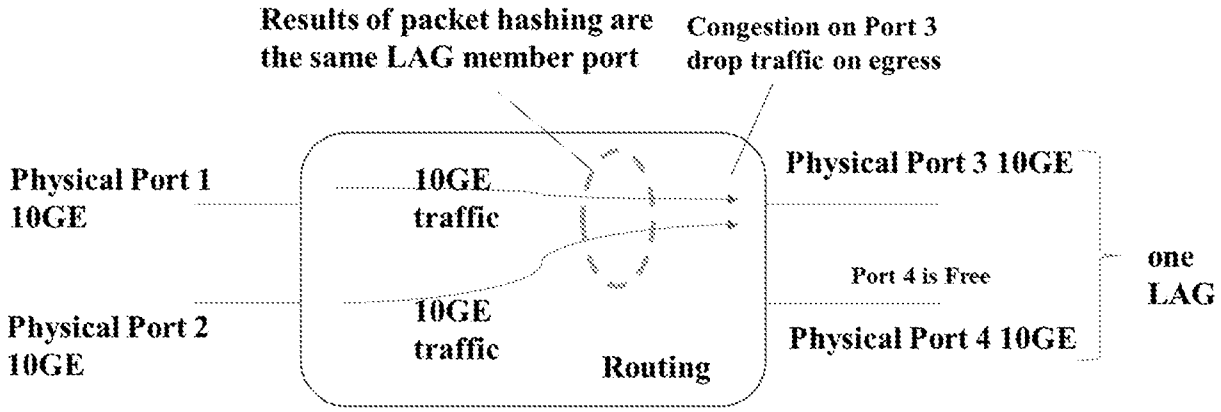
Results of packet hashing are the same LAG member port
Congestion on Port 3 drop traffic on egress
Physical Port 1 10GE
10GE traffic
Physical Port 3 10GE
Port 4 is Free
one LAG
Physical Port 2 10GE
10GE traffic
Physical Port 4 10GE
Routing

FIG. 1C

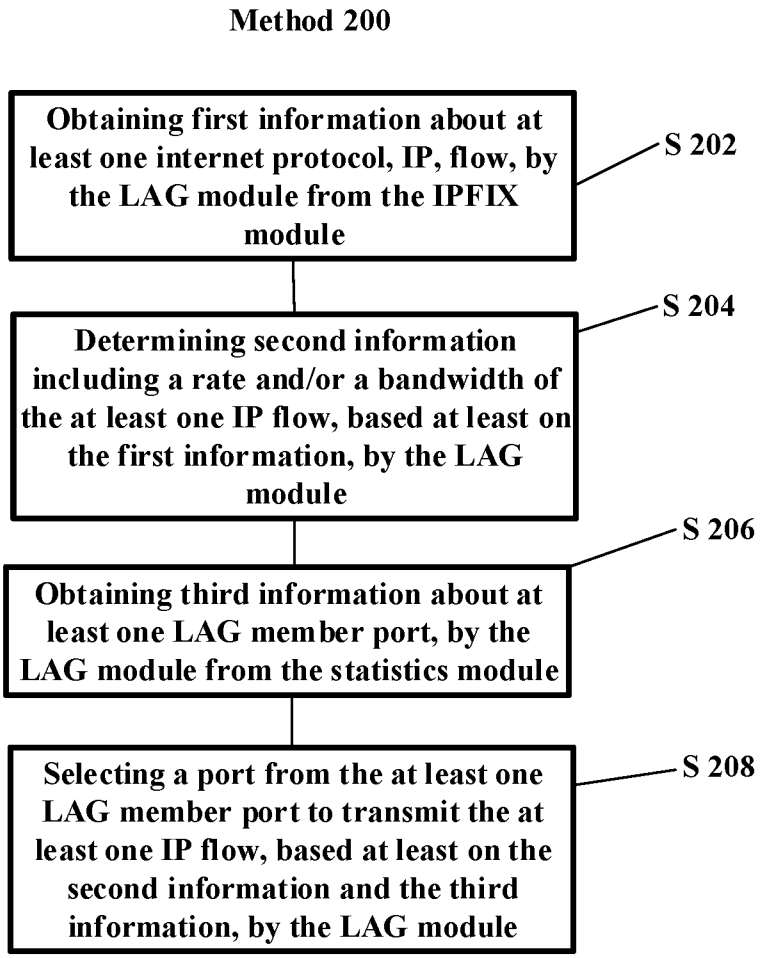
Method 200
Obtaining first information about at least one internet protocol, IP, flow, by the LAG module from the IPFIX module
S 202
Determining second information including a rate and/or a bandwidth of the at least one IP flow, based at least on the first information, by the LAG module
S 204
Obtaining third information about at least one LAG member port, by the LAG module from the statistics module
S 206
Selecting a port from the at least one LAG member port to transmit the at least one IP flow, based at least on the second information and the third information, by the LAG module
S 208

FIG. 2A

Method 200

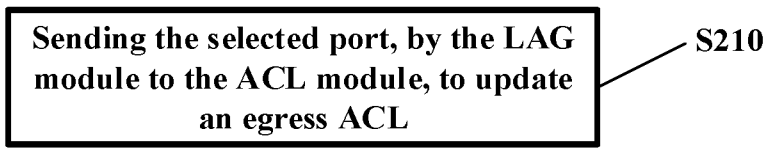

FIG. 2B

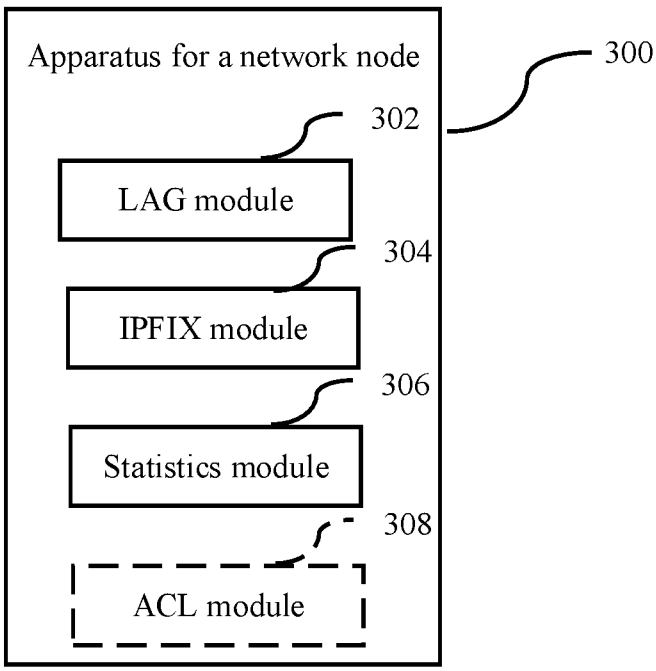

FIG. 3

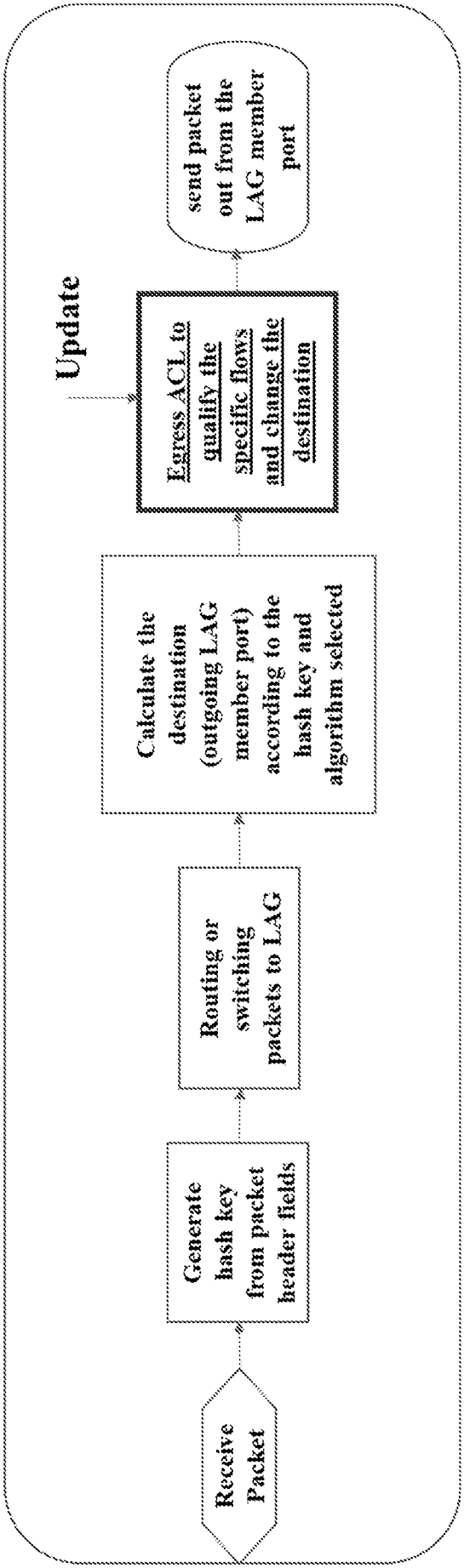
Update
Receive Packet
Generate hash key from packet header fields
Routing or switching packets to LAG
Calculate the destination (outgoing LAG member port) according to the hash key and algorithm selected
Egress ACL to qualify the specific flows and change the destination
send packet out from the LAG member port

FIG. 4

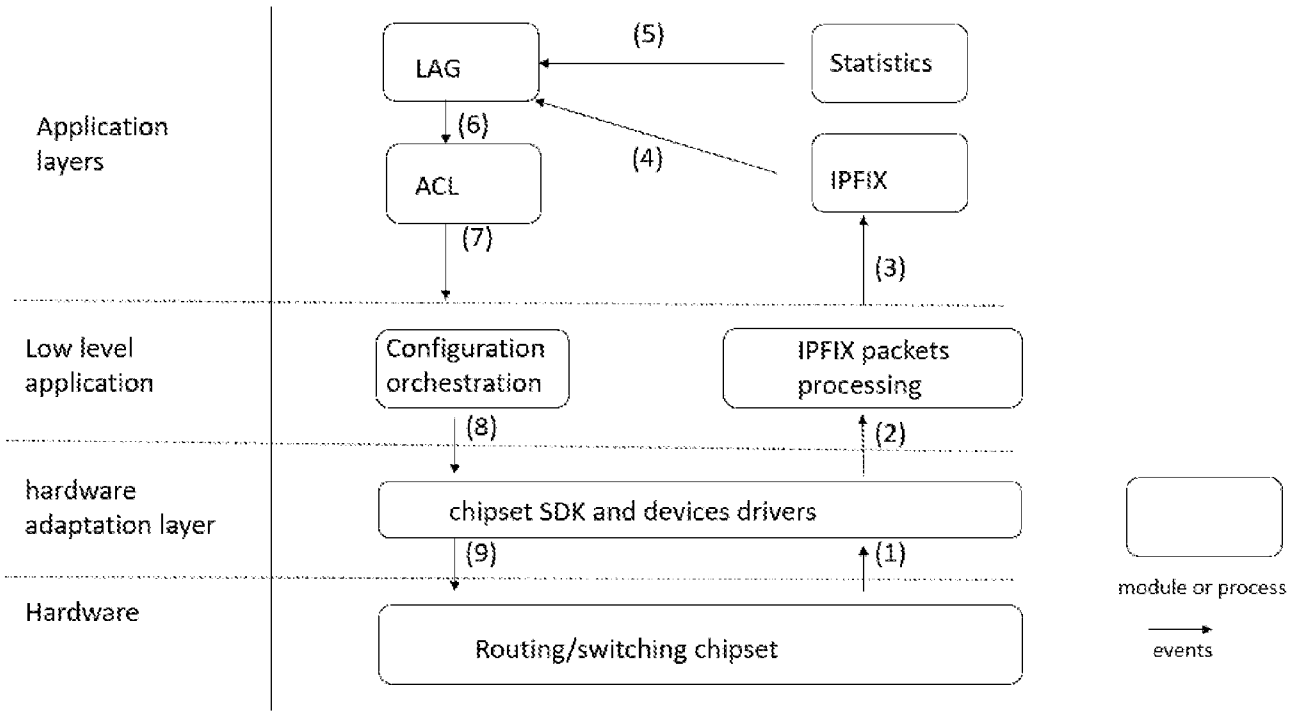
Application layers
Low level application
hardware adaptation layer
Hardware
LAG
Statistics
ACL
IPFIX
Configuration orchestration
IPFIX packets processing
chipset SDK and devices drivers
Routing/switching chipset
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
module or process
events

FIG. 5

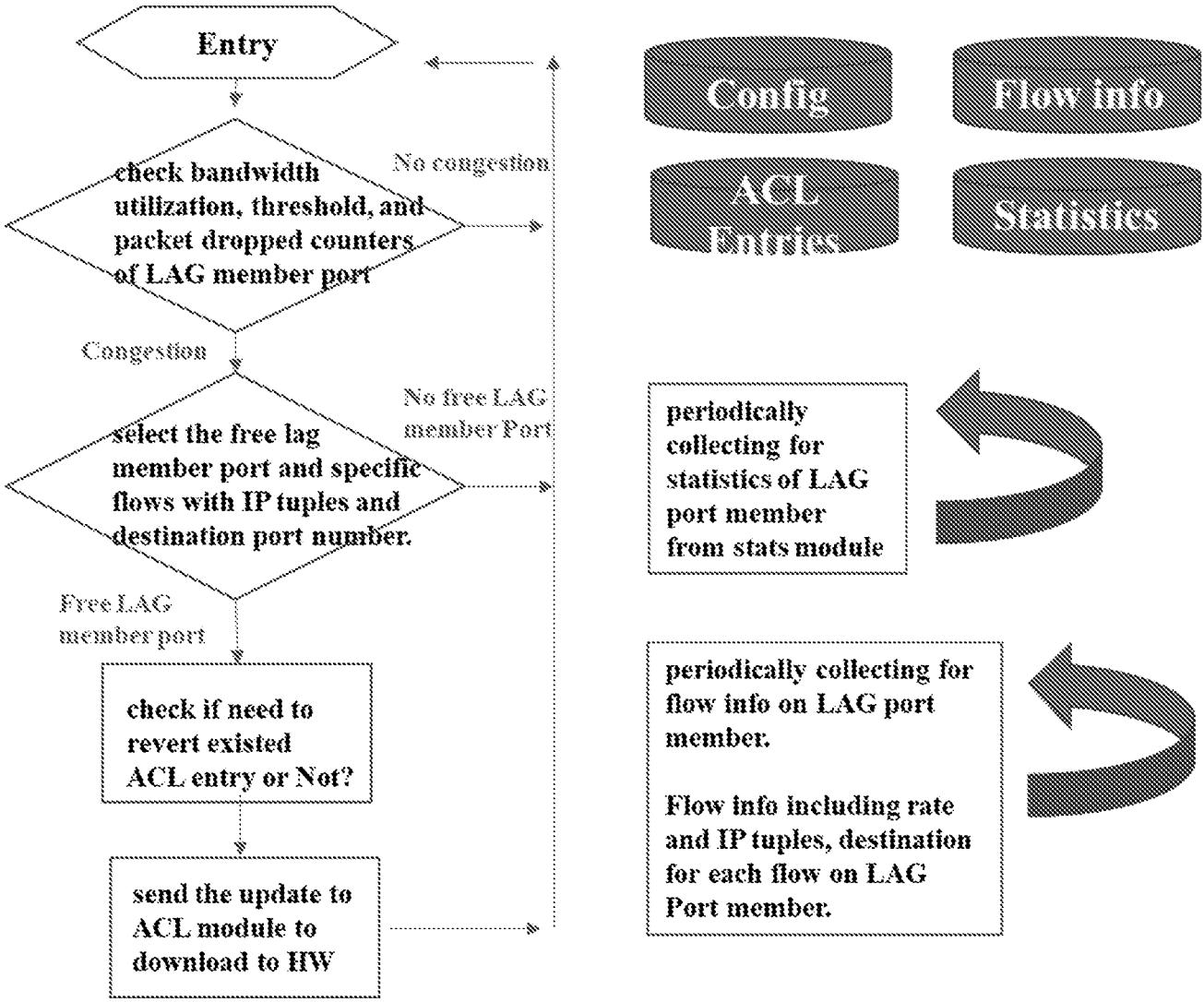
Entry
check bandwidth utilization, threshold, and packet dropped counters of LAG member port
No congestion
Congestion
select the free lag member port and specific flows with IP tuples and destination port number.
No free LAG member Port
Free LAG member port
check if need to revert existed ACL entry or Not?
send the update to ACL module to download to HW
Config
Flow info
ACL Entries
Statistics
periodically collecting for statistics of LAG port member from stats module
periodically collecting for flow info on LAG port member.
Flow info including rate and IP tuples, destination for each flow on LAG Port member.

FIG. 6

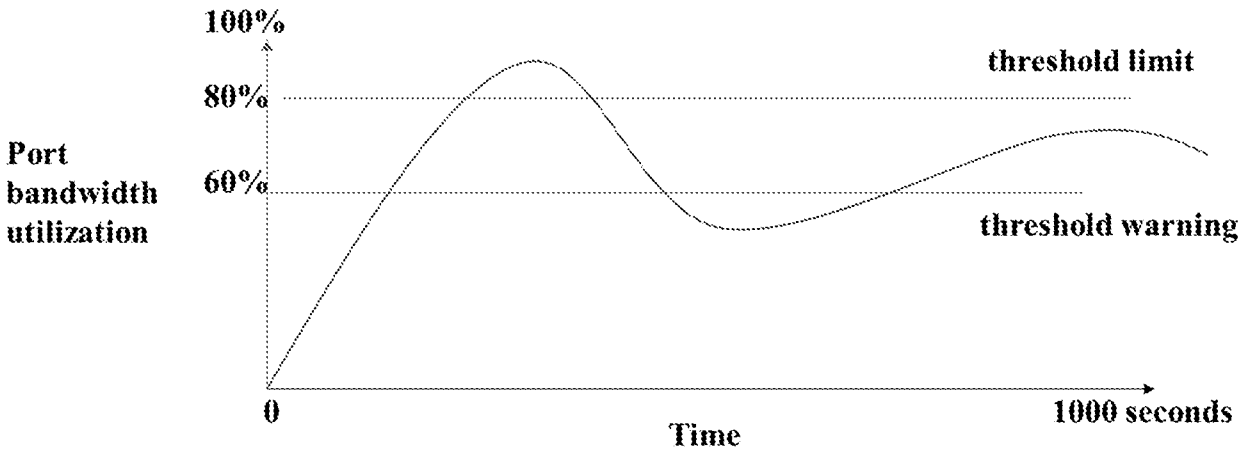
100%
80%
60%
threshold limit
threshold warning
Port bandwidth utilization
0
1000 seconds
Time

FIG. 7

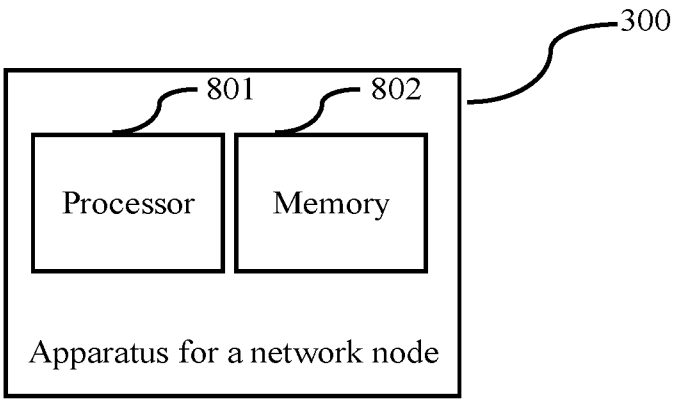
300
801
802
Processor
Memory
Apparatus for a network node

FIG. 8

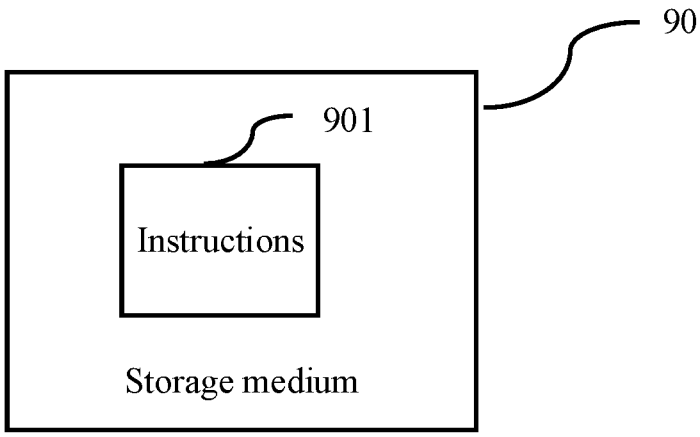
90
901
Instructions
Storage medium

FIG. 9

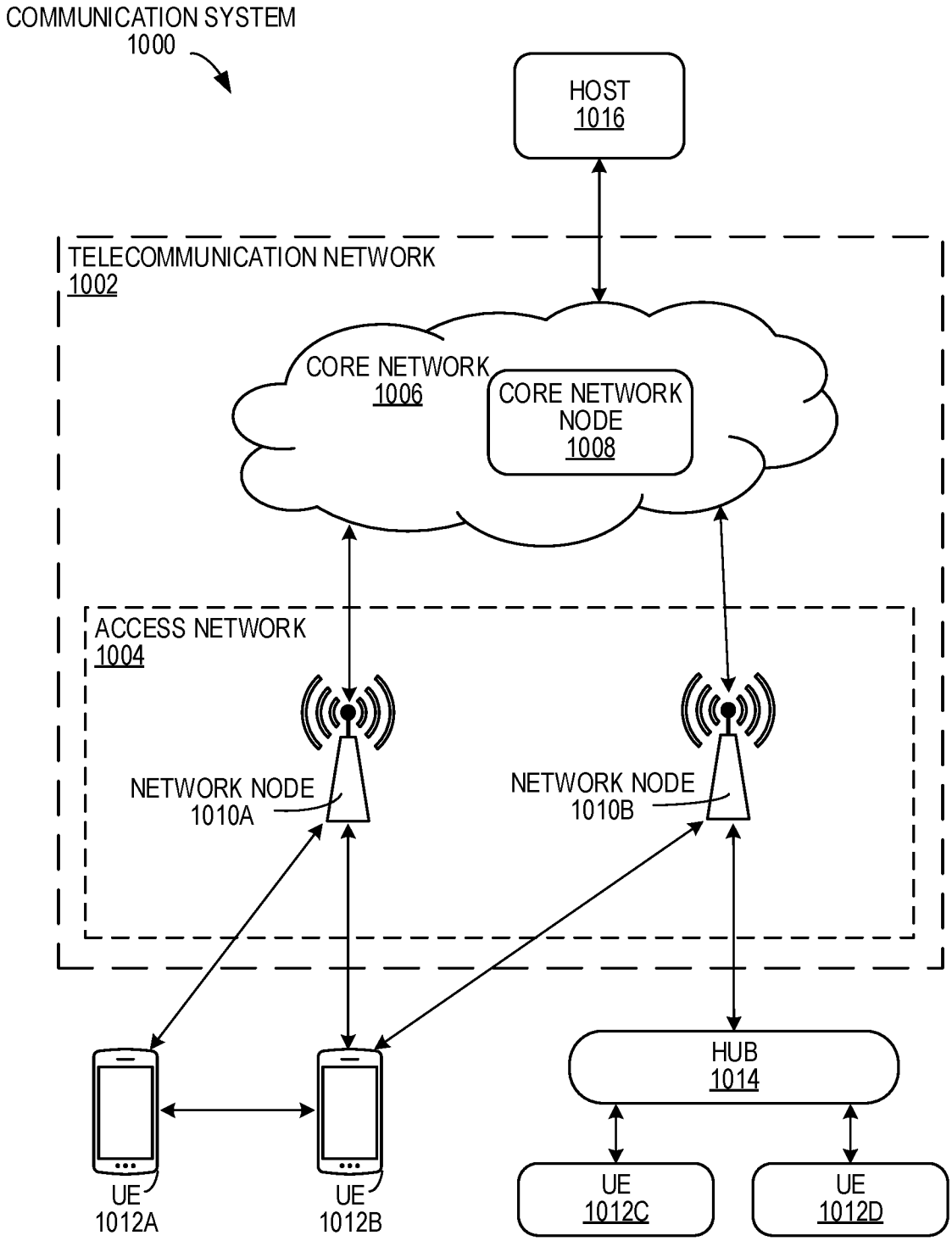
COMMUNICATION SYSTEM
1000
HOST
1016
TELECOMMUNICATION NETWORK
1002
CORE NETWORK
1006
CORE NETWORK
NODE
1008
ACCESS NETWORK
1004
NETWORK NODE
1010A
NETWORK NODE
1010B
HUB
1014
UE
1012A
UE
1012B
UE
1012C
UE
1012D

FIG. 10

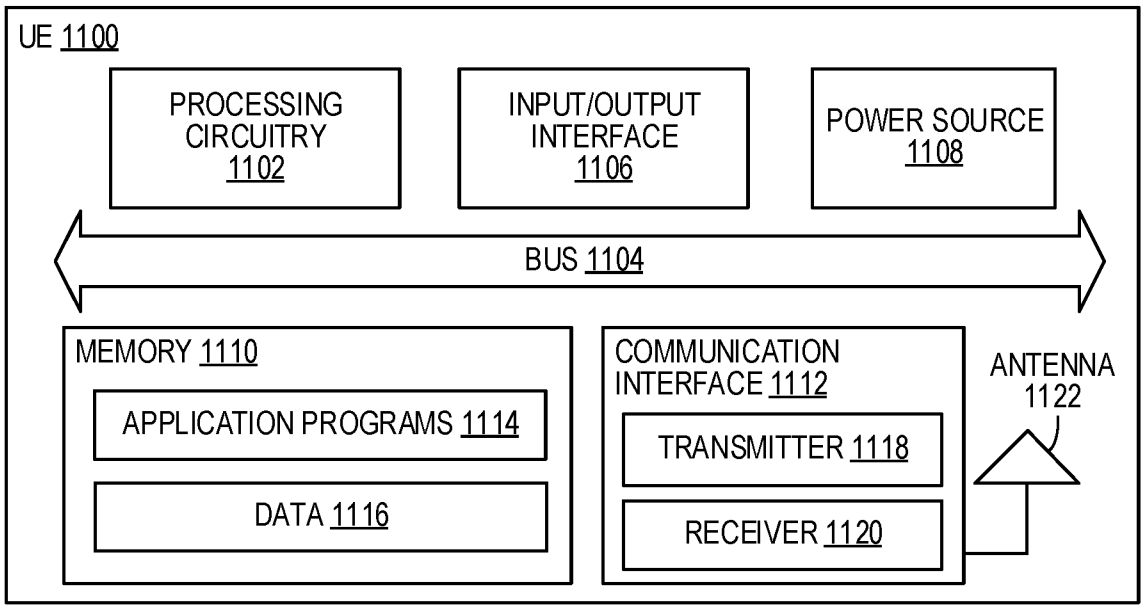
UE 1100
PROCESSING CIRCUITRY 1102
INPUT/OUTPUT INTERFACE 1106
POWER SOURCE 1108
BUS 1104
MEMORY 1110
APPLICATION PROGRAMS 1114
DATA 1116
COMMUNICATION INTERFACE 1112
TRANSMITTER 1118
RECEIVER 1120
ANTENNA 1122

FIG. 11

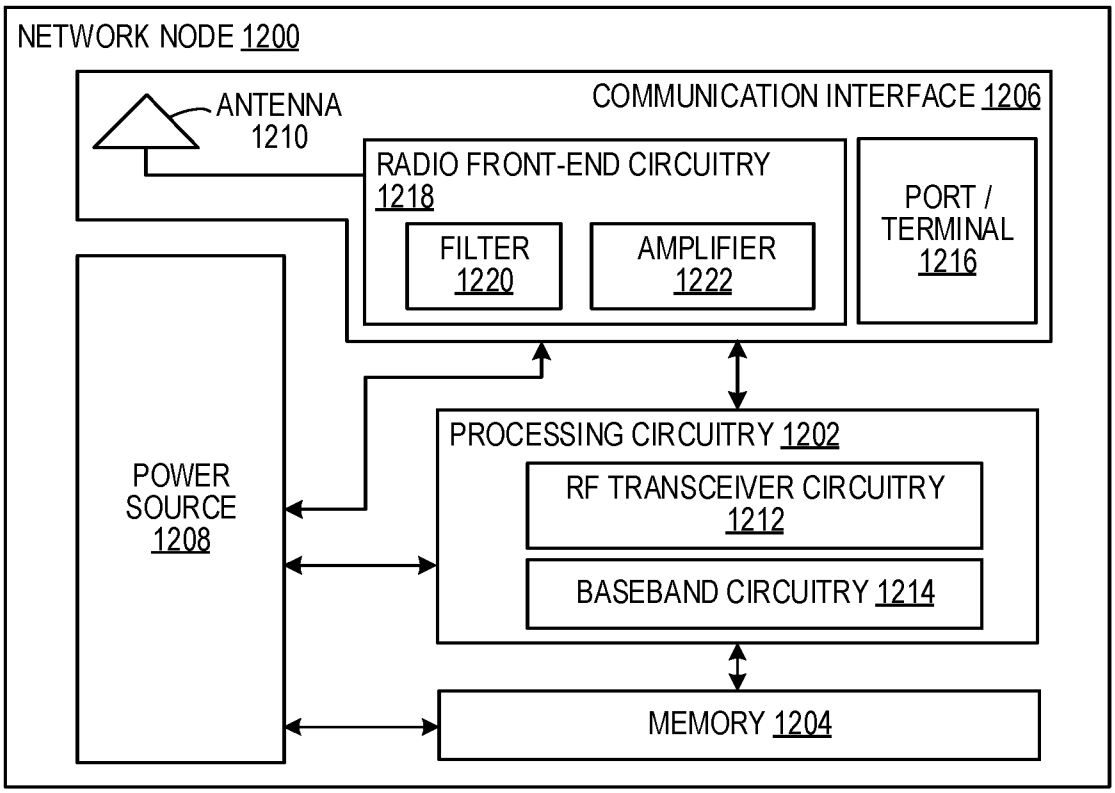
NETWORK NODE 1200
ANTENNA 1210
COMMUNICATION INTERFACE 1206
RADIO FRONT-END CIRCUITRY 1218
FILTER 1220
AMPLIFIER 1222
PORT / TERMINAL 1216
POWER SOURCE 1208
PROCESSING CIRCUITRY 1202
RF TRANSCEIVER CIRCUITRY 1212
BASEBAND CIRCUITRY 1214
MEMORY 1204

FIG. 12

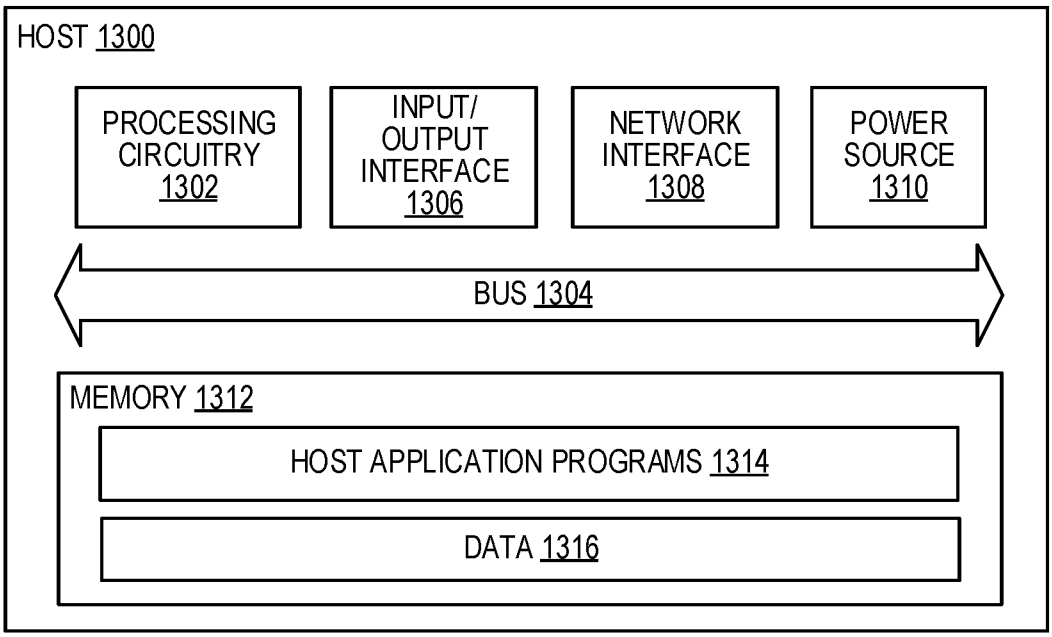
HOST 1300
PROCESSING CIRCUITRY 1302
INPUT/ OUTPUT INTERFACE 1306
NETWORK INTERFACE 1308
POWER SOURCE 1310
BUS 1304
MEMORY 1312
HOST APPLICATION PROGRAMS 1314
DATA 1316

FIG. 13

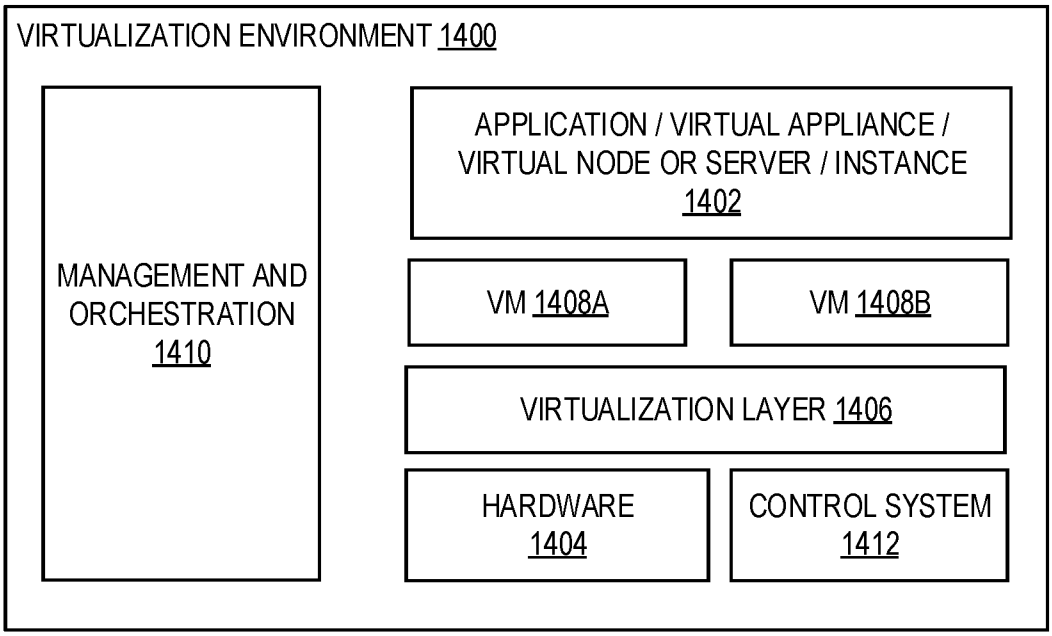
VIRTUALIZATION ENVIRONMENT 1400
MANAGEMENT AND ORCHESTRATION 1410
APPLICATION / VIRTUAL APPLIANCE / VIRTUAL NODE OR SERVER / INSTANCE 1402
VM 1408A
VM 1408B
VIRTUALIZATION LAYER 1406
HARDWARE 1404
CONTROL SYSTEM 1412

FIG. 14

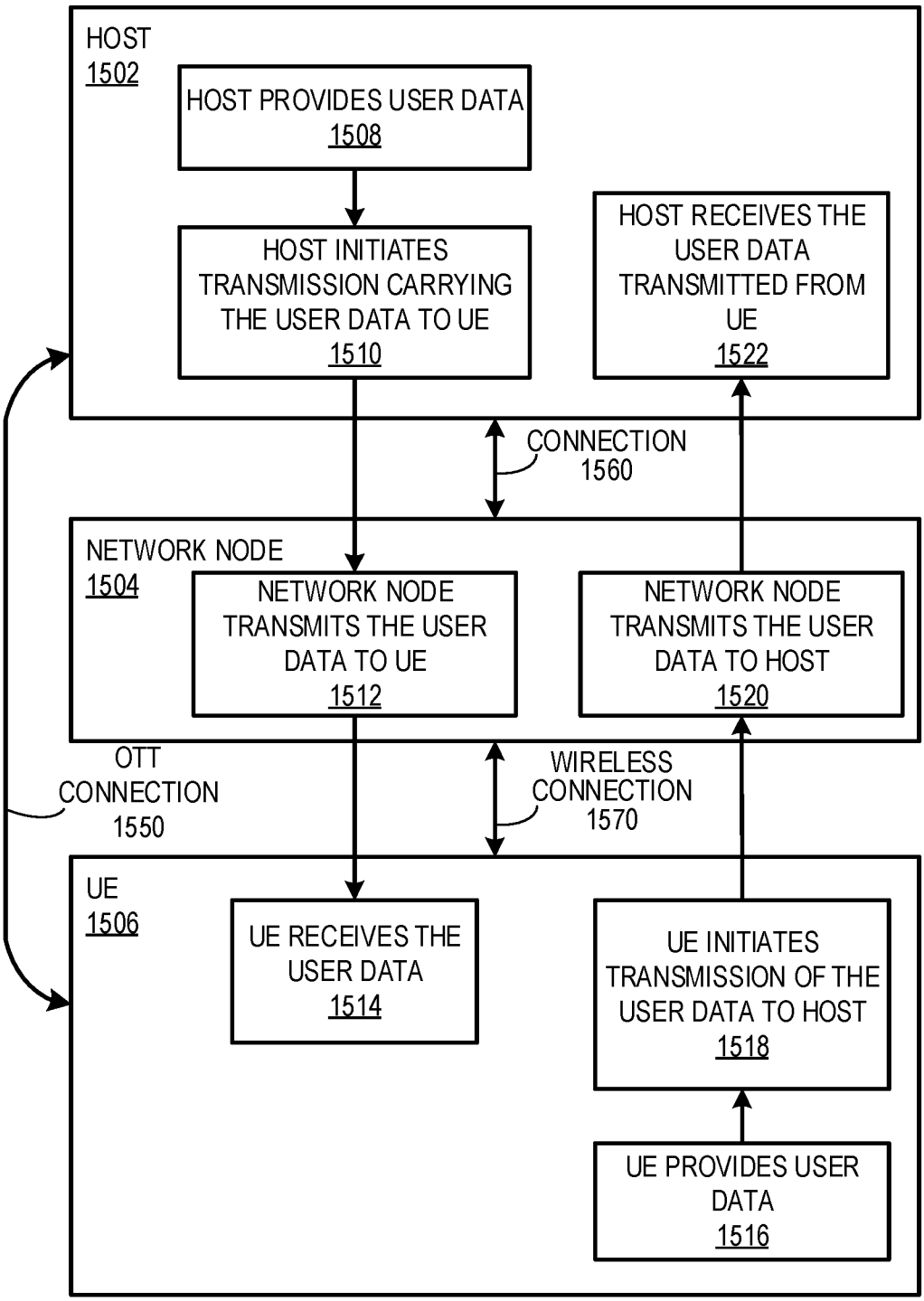
HOST
1502
HOST PROVIDES USER DATA
1508
HOST INITIATES TRANSMISSION CARRYING THE USER DATA TO UE
1510
HOST RECEIVES THE USER DATA TRANSMITTED FROM UE
1522
CONNECTION
1560
NETWORK NODE
1504
NETWORK NODE TRANSMITS THE USER DATA TO UE
1512
NETWORK NODE TRANSMITS THE USER DATA TO HOST
1520
OTT CONNECTION
1550
WIRELESS CONNECTION
1570
UE
1506
UE RECEIVES THE USER DATA
1514
UE INITIATES TRANSMISSION OF THE USER DATA TO HOST
1518
UE PROVIDES USER DATA
1516

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/080165

A. CLASSIFICATION OF SUBJECT MATTER

H04L 47/41(2022.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L

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

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

WPI;EPODOC;CNKI;CNPAT:rate, bandwidth, link, aggregation, group, LAG, load, balance, congest, LAG, port

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102469019 A (ZTE CORP.) 23 May 2012 (2012-05-23) description, paragraphs [0041]-[0063]	1-12
A	CN 103401801 A (CENTEC NETWORK SUZHOU CO., LTD.) 20 November 2013 (2013-11-20) the whole document	1-12
A	CN 102263697 A (HANGZHOU H3C TECHNOLOGIES CO., LTD.) 30 November 2011 (2011-11-30) the whole document	1-12
A	CN 101022456 A (HUAWEI TECHNOLOGIES CO., LTD.) 22 August 2007 (2007-08-22) the whole document	1-12
A	CN 113422731 A (EVERSEC BEIJING TECHNOLOGY CO., LTD.) 21 September 2021 (2021-09-21) the whole document	1-12
A	US 2017230294 A1 (CIENA CORP.) 10 August 2017 (2017-08-10) the whole document	1-12

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"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	Date of mailing of the international search report
08 November 2022	**25 November 2022**
Name and mailing address of the ISA/CN **National Intellectual Property Administration, PRC** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing** **100088, China** Facsimile No. **(86-10)62019451**	Authorized officer **XU,Quan** Telephone No. **86-(010)-53961794**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/080165

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 102469019 A	23 May 2012	WO 2012065466 A1	24 May 2012
CN 103401801 A	20 November 2013	None	
CN 102263697 A	30 November 2011	WO 2013017017 A1	07 February 2013
CN 101022456 A	22 August 2007	None	
CN 113422731 A	21 September 2021	None	
US 2017230294 A1	10 August 2017	IN 201611003986 A	04 August 2017