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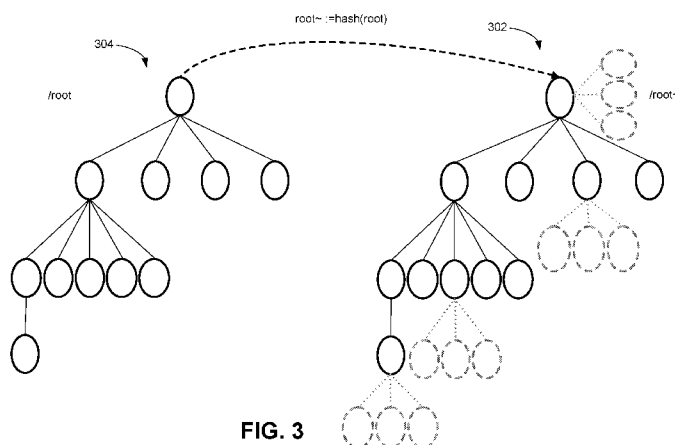


FIG. 3

(57) Abstract: Methods, apparatus, systems, devices, and computer program products directed to publisher/subscriber management in information-centric networking are provided. Among the provided methods is a method that may include introducing a system-information namespace in addition to an exchanged-information namespace, which may be algorithmically associated or linked, allowing for loosely establishing system state information, including group-related or other management information, such as group sizes, states and/or others; and carrying out operations associated to, and/or based on, such management information, which in turn can support various functions, such as content management, application-level functions and/or functions associated with, and/or relating to, publisher-subscriber (pub/sub) communication relationships.

**METHODS, APPARATUSES AND SYSTEMS DIRECTED TO
PUBLISHER/SUBSCRIBER GROUP MANAGEMENT IN INFORMATION-CENTRIC
NETWORKING**

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 62/175,199 filed 12-Jun-2015 (Attorney Docket Reference 12555US01), which is incorporated herein by reference.

BACKGROUND

[0002] The present invention relates to the field of wireless communications and information-centric networking (ICN) and, more particularly, to methods, apparatus and systems for use with information-centric networking.

[0003] The Internet may be used to facilitate content distribution and retrieval. In existing Internet protocol (IP) networks, computing nodes are interconnected by establishing communications using IP addresses of these nodes. In ICN, users are interested in the content itself, rather than where the content is stored. Content distribution and retrieval may be performed in ICN systems based on names (i.e., identifiers (IDs)) of content, rather than IP addresses.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A more detailed understanding may be had from the detailed description below, given by way of example in conjunction with drawings appended hereto. Figures in such drawings, like the detailed description, are examples. As such, the Figures and the detailed description are not to be considered limiting, and other equally effective examples are possible and likely. Furthermore, like reference numerals ("ref.") in the Figures indicate like elements, and wherein:

[0005] Figure 1A is a system diagram of an example communications system in which one or more disclosed embodiments may be implemented;

[0006] Figure 1B is a system diagram of an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in Figure 1A;

[0007] Figure 1C is a system diagram of example radio access networks and example core networks that may be used within the communications system illustrated in Figure 1A;

[0008] Figure 2 is a block diagram illustrating a representative information-centric networking (ICN) system;

[0009] Figure 3 is a block diagram illustrating an example system-information namespace algorithmically associated or linked to an information namespace;

[0010] Figure 4 is a block diagram illustrating an example information namespace densified with system state information;

[0011] Figure 5 is a flow diagram illustrating an example procedure implementing timeout handling in connection with IP-over-ICN communications;

[0012] Figure 6 is a flow diagram illustrating an example procedure implementing quality of service (QoS) based ICN transmissions;

[0013] Figure 7 is a flow diagram illustrating an example procedure implementing information update scheduling in an ICN system; and

[0014] Figure 8 is a flow diagram illustrating an example procedure implementing load distribution in an ICN system.

DETAILED DESCRIPTION

[0015] In the following detailed description, numerous specific details are set forth to provide a thorough understanding of embodiments and/or examples disclosed herein. However, it will be understood that such embodiments and examples may be practiced without some or all of the specific details set forth herein. In other instances, well-known methods, procedures, components and circuits have not been described in detail, so as not to obscure the following description. Further, embodiments and examples not specifically described herein may be practiced in lieu of, or in combination with, the embodiments and other examples described, disclosed or otherwise provided explicitly, implicitly and/or inherently (collectively "provided") herein.

[0016] Example Communications System

[0017] The methods, apparatuses and systems provided herein are well-suited for communications involving both wired and wireless networks. Wired networks are well-known. An overview of various types of wireless devices and infrastructure is provided with respect to Figures 1A-1C, where various elements of the network may utilize, perform, be arranged in accordance with and/or be adapted and/or configured for the methods, apparatuses and systems provided herein.

[0018] Figure 1A is a diagram of an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access

(TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), and the like.

[0019] As shown in Figure 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d may be configured to transmit and/or receive wireless signals, and may include user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, consumer electronics, a terminal or like-type device capable of receiving and processing compressed video communications, or like-type device.

[0020] The communications systems 100 may also include a base station 114a and a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the core network 106, the Internet 110, and/or the networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, a media aware network element (MANE) and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0021] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In another embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

[0022] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0023] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0024] In another embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A).

[0025] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0026] The base station 114b in Figure 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, etc.) to establish a picocell or femtocell. As shown in Figure 1A, the base station 114b may have a direct connection to the

Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the core network 106.

[0027] The RAN 104 may be in communication with the core network 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. For example, the core network 106 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in Figure 1A, it will be appreciated that the RAN 104 and/or the core network 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the RAN 104, which may be utilizing an E-UTRA radio technology, the core network 106 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[0028] The core network 106 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another core network connected to one or more RANs, which may employ the same RAT as the RAN 104 or a different RAT.

[0029] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities, i.e., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU 102c shown in Figure 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0030] Figure 1B is a system diagram of an example WTRU 102. As shown in Figure 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 106, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and

other peripherals 138. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0031] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a graphics processing unit (GPU), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While Figure 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0032] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In another embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0033] In addition, although the transmit/receive element 122 is depicted in Figure 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0034] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

[0035] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a

liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 106 and/or the removable memory 132. The non-removable memory 106 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0036] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0037] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0038] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

[0039] Figure 1C is a system diagram of the RAN 104 and the core network 106 according to an embodiment. As noted above, the RAN 104 may employ a UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may

also be in communication with the core network 106. As shown in Figure 1C, the RAN 104 may include Node-Bs 140a, 140b, 140c, which may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. The Node-Bs 140a, 140b, 140c may each be associated with a particular cell (not shown) within the RAN 104. The RAN 104 may also include RNCs 142a, 142b. It will be appreciated that the RAN 104 may include any number of Node-Bs and RNCs while remaining consistent with an embodiment.

[0040] As shown in Figure 1C, the Node-Bs 140a, 140b may be in communication with the RNC 142a. Additionally, the Node-B 140c may be in communication with the RNC 142b. The Node-Bs 140a, 140b, 140c may communicate with the respective RNCs 142a, 142b via an Iub interface. The RNCs 142a, 142b may be in communication with one another via an Iur interface. Each of the RNCs 142a, 142b may be configured to control the respective Node-Bs 140a, 140b, 140c to which it is connected. In addition, each of the RNCs 142a, 142b may be configured to carry out or support other functionality, such as outer loop power control, load control, admission control, packet scheduling, handover control, macrodiversity, security functions, data encryption, and the like.

[0041] Figure 1C is a system diagram of the RAN 104 and the core network 106 according to another embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the core network 106.

[0042] The RAN 104 may include eNode Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode Bs while remaining consistent with an embodiment. The eNode Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode B 160a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a.

[0043] Each of the eNode Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in Figure 1C, the eNode Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0044] The core network 106 shown in Figure 1C may include a mobility management gateway (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While each of the foregoing elements are depicted as part of the core network 106, it will

be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0045] The MME 162 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular SGW during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may also provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

[0046] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0047] The SGW 164 may also be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0048] The core network 106 may facilitate communications with other networks. For example, the core network 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the core network 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network 106 and the PSTN 108. In addition, the core network 106 may provide the WTRUs 102a, 102b, 102c with access to the networks 112, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0049] Representative ICN System

[0050] FIG. 2 is a block diagram illustrating a representative ICN system 200. The ICN system 200 may include a rendezvous point (RP) 201, a topology manager (TM) 203, first and second network attachment points (NAPs) 205, 207 and forwarding nodes (FNs) 209, 211. As described in more detail below, each of the NAPs 205, 207 and TM 203 may undertake both publisher and subscriber roles. As publishers, the NAPs 205, 207 and TM 203 may publish to and/or at the RP 201; and as subscribers, the NAPs 205, 207 and TM 203 may subscribe to and/or at the RP 201.

[0051] The RP 201 (e.g., logically centralized and/or physically centralized) may perform matching of publishers and subscribers. A publisher may be an application endpoint and/or any network node which can deliver (e.g., publish) content. A subscriber may be an application endpoint (e.g., a different application endpoint and/or any network node, which can receive or request (e.g., subscribe to) content. The incoming subscription may be processed by the publisher at the time of the incoming subscription. The incoming publication may be processed by the subscriber at the time of the incoming publication.

[0052] After a match (e.g., a successful match), the RP 201 may facilitate the delivery of the information as instructed by (e.g., provided for using) the match information. In certain representative embodiments, the TM 203 may forward the match (and/or enable forwarding of the requested content) of one or more publishers to one or more subscribers. The TM 203 may determine a source route (e.g., for a stateless forwarding operation) within the ICN system 200, e.g., via FNs 209, 211. In certain representative embodiments, a root node may be forwarded the requested content. The root node may forward and/or route the requested content using (e.g., down) a well-defined scope tree (e.g., associated with one or more nodes of the network). In certain representative embodiments, forwarding information bases (FIBs) may be pre-defined and the FS may be set (e.g., “fixed” from the point of view of forwarding each particular content).

[0053] Although not shown, the ICN system 200 may include any number of RPs, which, for example, may each manage a portion of the publishers and/or subscribers. The RPs may provide for matching of publishers and subscribers and may be provided as a standalone unit, a server and/or a part of an existing network node. The ICN system 200 may include more NAPs and TMs and more or fewer FNs than shown in Figure 2.

[0054] Overview

[0055] Recent research efforts, such as in areas of information-centric networking (ICN), have been studying novel approaches to routing information rather than merely sending bit packets from endpoint A to endpoint B. Some approaches offer spatial and temporal decoupling of senders and receivers of information in contrast to the strong coupling of send and receive operations in the current Internet (i.e., from address A to address B). Such decoupling bears many advantages, including an ability to provide the information from multiple alternative sources rather from a single server, for example.

[0056] However, there may also be drawbacks that stem from such decoupling, such as, a lack of knowledge as to whether or not any interested party (for a piece of information) actually exists or what a current ‘audience size’ for a particular information item is. This information along

with other system state information may be useful for various operation, such as content management or application-level functions.

[0057] The decoupling may also result in an opportunity to garner information, including, for example, knowledge as to whether or not any interested party (for a piece of information) actually exists or what a current audience size for a particular information item is. This information along with other system state information may be very useful for supporting various functions, such, as content management, application-level functions and/or functions associated with, and/or relating to, publisher-subscriber (pub/sub) communication relationships.

[0058] Provided herein are procedures, methods, architectures, apparatus, systems, devices, and computer program products directed to publisher/subscriber group management in ICN systems. Pursuant to the methodologies and technologies provided herein, various system elements may be made (more) aware of some overall system state, and take such information into account when, or in connection with, performing an ICN action, such as, publishing, subscribing to and/or transmitting information items. Examples of other ICN actions include constraint-based computation of the source route at the TM 203 and implementation of ICN application level logic.

[0059] In an embodiment, an entity of ICN element (e.g., a publisher) wants to perform an ICN action (e.g., to transmit information). In anticipation of carrying out the ICN action, the ICN element may first carry out a check/test on some system property (e.g., run a check on an online subscriber count property to determine whether any subscribers are actually online), and then may take such into account in connection with carrying out the ICN action (e.g., transmitting or not transmitting the information based on the determination). The system information may be obtained by the ICN element by subscribing to it – much in the same way as any ICN entity can subscribe to any information, as further detailed herein. The ICN element may undertake both publisher and subscriber roles; e.g., as an information publisher and as a subscriber to the online subscriber count for the information it plans to publish.

[0060] Among the provided procedures, methods, architectures, apparatus, systems, devices, and computer program products is a method that may include introducing a namespace for system information ("system-information namespace") in addition to a namespace for exchanged (i.e., actual, to-be-transmitted) information ("exchanged-information namespace"), which may be algorithmically associated or linked, allowing for loosely establishing system state information, including group-related or other management information (collectively "management information"), such as group sizes, states and/or others; and carrying out operations associated to, and/or based on, such management information, which in turn can support various functions,

such as content management, application-level functions and/or functions associated with, and/or relating to, publisher-subscriber (pub/sub) communication relationships.

[0061] In an embodiment, the ICN identifier/name (collectively "ICN identifier") of the system state information may be algorithmically derived from the ICN identifier of the exchanged information. This way, the ICN identifier of the system state information to issue subscriptions to may be determined from the ICN identifier of the exchanged information.

[0062] Among the provided methods is a method that may include associating (e.g., algorithmically associating or linking) management information to exchanged information in ICN systems. In an embodiment, the ICN identifier of the management information may be algorithmically derived from the ICN identifier of the exchanged information; allowing for determination of the ICN identifier of the management information to issue subscriptions to from the ICN identifier of the exchanged information.

[0063] Representative Algorithmically Associated Management Information

[0064] Figure 3 illustrates an example system-information namespace 302. The system-information namespace 302 defines a structure of instantiated values of management information that may be published and/or subscribed to. The system-information namespace 302 may be algorithmically associated or linked (collectively "associated") to an information namespace 304 under consideration for transmission within an ICN system (e.g., a namespace housing video content or other web-like information). For simplicity of exposition, the associated namespaces of Figure 3 are described with reference to the ICN system 200 of Figure 2. The associated namespaces and accompanying techniques set forth herein may be deployed in systems other than the ICN system 200 of Figure 2, as well.

[0065] The information namespace 304 may define, or be arranged using, an information structure (e.g., a directed acyclic graph (DAG)) that may include one or more information items and one or more scopes (i.e., trees of information). The information items may be, include and/or refer to information made available by one or more publishers for dissemination to one or more subscribers, information requested by the subscribers and/or information made available by the subscribers for dissemination to the publishers. Examples of the information item include video content and other web-like information. Transmission of the information items within the ICN system 200 occurs responsive to operations (e.g., rendezvous, topology management, forwarding and physical media (RTFM) operations) carried out on the information namespace.

[0066] The system-information namespace 302 may define, or be arranged using, an information structure, such as, for example a DAG. The system-information namespace 302 may include an encoded or otherwise translated copy of some or all of the information

namespace 304. The encoding may be any type of encoding that permits an unambiguous identification and/or recreation of a constituent part of the information namespace 304 from the corresponding encoded version of the system-information namespace 302. The system-information namespace 302 may also include, under (or otherwise disposed in connection with) any of the encoded scopes and information items, one or more associated management information items and/or scopes of management information items ("management-information scopes").

[0067] In one embodiment, the system-information namespace 302 may be established or otherwise generated as follows. A scope, */root~*, may be established in the system-information namespace 302 using *root~:=hash(root)* so as to algorithmically associate */root~* to the root, */root*, of the information namespace 304. The scope, */root~*, may be the root of the system-information namespace 302. Alternatively, the scope, */root~*, may be established directly, or indirectly via one or more other scopes, under the root of the system-information namespace 302. After scope, */root~*, is established, the portion of the information namespace 304 from under */root* may be replicated or otherwise incorporated into the system-information namespace 302 under */root~*. After (or in connection with) such incorporation, management information items and/or management-information scopes (collectively "management information") associated to the incorporated scopes and/or information items may be established under (or otherwise disposed in connection with) such incorporated scopes and/or information items.

[0068] By establishing the system-information namespace 302 separate from the information namespace 304 (instead of simply adding the management information into the information namespace 304), any of the information items incorporated from the information namespace 304 may be turned into (effectively operate as) scopes within the system-information namespace 302 by adding, under such incorporated information items, associated management information. As a scope, a subscription to the incorporated information item may return identifiers of associated management information and not the actual information item (e.g., video). Simply adding management information directly under an information item in the information namespace 304 also turns the information item into a scope; the consequence of which is that a subscription to the information item may return identifiers of the management information, but not the actual information item, as desired. As a separate namespace that is algorithmically associated to the information namespace 304, the system-information namespace 302 may be considered a pure management namespace in that it has no direct association to the content that is transmitted within information namespace 304.

[0069] Having management information under an information item within the information namespace 304 might not pose any identifier collision problem in the associated system-information namespace 302 because the information item is turned into a scope within the system-information namespace 302 and the management information may be identified through scope-locally unique identifiers. Similarly, incorporating management information under an incorporated information item (from the information namespace 304) might not pose any identifier collision problem since the incorporated information item is turned into a scope under the scope, $/root\sim$, within the system-information namespace 302, where $root\sim := hash(root)$ (i.e., the management information may be identified through scope-locally unique identifiers).

[0070] Incorporating the management information under a scope within the system-information namespace 302 without carrying out a collision avoidance procedure on corresponding identifiers of the management information may potentially lead to identifier collision due to identifiers under such scope already existing and to no guarantee for a choice of identifier that does not collide with any chosen management information identifier. In some embodiments, a collision avoidance procedure, which may be executed before or in connection with adding the management information to the system-information namespace 302, may be carried out by (i) determining whether any of the existing items/scopes identifiers and a prospective management information identifier, MID , collide; (ii) replacing the management identifier, MID , with $MID\sim = hash(MID)$ if it collides; and ((iii) repeating (i) and (ii) until no collisions occur. Other functions may be used for $MID\sim$, including, for example, $MID\sim = MID + 1$ or $MID\sim = MID - 1$.

[0071] Figure 4 is a block diagram illustrating an example information namespace 400. The information namespace 400 may be established so as to permit co-existence of management information with information items that may be transmitted within the information namespace. For example, the information namespace 400 may be established to include management information relating to an information item or scope by algorithmically associating the management information to such information item or scope. Such management information may form a scope under which the related management information, if any, may be instantiated.

[0072] Establishing the management information within the information namespace 400 may be carried out by forming a management information item, $CID\sim$, within the information namespace 400 using $CID\sim := hash(CID)$, where CID is an information item to which the management information is associated. Because the management information item, $CID\sim$, forms a scope, the management information may be instantiated thereunder (e.g., similar to the approach described above with respect to Figure 3).

[0073] An advantage of the foregoing approach is that collision avoidance procedures may be simpler (e.g., a hash is executed repeatedly if the generated management information item, *CID~*, already exists). The approach of establishing management information within an information namespace, such as described with respect to Figure 4, might result in densification of the information namespace 400. In some embodiments, the information namespace 400 may become half saturated with management information. Use of collision avoidance procedures may be increasingly likely the fuller the information namespace 400 becomes.

[0074] Representative Management Information

[0075] The management information items that enrich the namespaces may be published as instantiated values and be subscribed to by various consumers, e.g., NAPs, TMs, etc. For this, each particular management information *i* item may be assigned a corresponding identifier *MID_i*. The assigned identifier, *MID_i*, may be used to represent respective management information items incorporated into a namespace. These identifiers, *MID_i*, may be standardized and/or based on another form of agreement between elements populating and/or using the namespace (e.g., within a proprietary application).

[0076] The management information may include any information relating to a communication relationship between one or more publishers of, and one or more subscribers to, an information item. Examples for the management information include, for example, subscriber group size information, publisher group size information, geographic distribution information, state information, QoS information, and semantic information.

[0077] The subscriber group size information may indicate how many subscribers have a current interest in the managed information item. The RP 201 may provide a current value for this information. For example, the RP 201 may publish a current value of the number of subscribers according to the namespace 302 (Figure 3), the namespace 400 (Figure 4) or other like-type namespace.

[0078] The publisher group size information may indicate how many publishers have availability of the managed information item. The RP 201 may provide a current value for this information. For example, the RP 201 may publish a current value of the number of publishers according to the namespace 302 (Figure 3), the namespace 400 (Figure 4) or other like-type namespace.

[0079] The geographic distribution information may indicate a geographic distribution of publishers and/or subscribers according to a (e.g., agreed) geographic metric, such as, for example, continent, nation, county, etc.. The RP 201 may provide such statistics based on, for

example, publisher/subscriber information, combined with autonomous system (AS) level information.

[0080] The state information may indicate a particular state that the managed information item currently is in. The state information may be in accordance with an agreed upon application-specific semantic. Examples of the state information include RINGING, WAITING or similar for a managed information item that represents a voice call. Any application function provider may publish the current state information. Such publication may be carried out according to some application-specific logic.

[0081] The QoS information may indicate a particular (e.g., expected) quality-of-service for appropriate transfer of the managed information item in the ICN system 200. The QoS information may be published by an information owner and/or any of its publishers.

[0082] The semantic information may indicate information about a semantic being used in the exchange of the managed information item. For instance, the managed information item with identifier *CID* might generally indicate some form of location information, while the respective management information might indicate which exact semantics are used to interpret the managed information (e.g., GPS, NMEA, GMX, KML, etc.).

[0083] **Representative Operations Performed on Management Information**

[0084] *Timeout handling for IP-over-ICN Communications*

[0085] Figure 5 is a flow diagram illustrating an example procedure 500 implementing timeout handling in connection with IP-over-ICN communications. For simplicity of exposition, the procedure 500 is described with reference to the ICN system 200 of Figure 2. The procedure 500 may be carried out in other systems, as well.

[0086] The NAP 205 may receive one or more IP packets (502) for transmission within the ICN system 200. The arrival of each IP packet at the NAP 205 may operate as a trigger to perform various ICN actions to accommodate the ICN pub/sub paradigm. For instance, the NAP 205 may buffer the IP packet, extract at least its destination IP address and map (or otherwise convert) the destination IP address into an appropriate ICN identifier (504). The NAP 205 may thereafter become a publisher of the IP packet by publishing the availability of an information item (i.e., the IP packet) to the RP 201. Assuming at least one receiver NAP is subscribed the appropriate ICN identifier (e.g., NAP 207) and a publisher-subscriber communication relationship exists among the NAP 205 and NAP 207 and/or any other receiver NAP, if any (collectively "receiver NAP(s) 207"), the NAP 205 is able to generate ICN headers configured for forwarding to the receiver NAPs 207, encapsulate the IP packet in the ICN headers and publish the encapsulated IP packet to the ICN identifier towards the receiver NAPs 207. The

aforementioned temporal and spatial decoupling of ICN might result in blocking of the send operation from the sender NAP 205 when no NAPs are subscribed to the ICN identifier, and in the send operation remaining blocked until a receiver NAP and/or other subscriber subscribes to the ICN identifier. More generally, sending an IP packet to an IP address that is currently not connected in the network may lead to blocking at a sender NAP when no subscriber to such IP address exists.

[0087] Before becoming a publisher of the IP packet, the NAP 205 may issue, to the RP 201, a subscription to a subscriber group size information item associated to the ICN identifier **(506)**. The NAP 205 may receive, from the RP 201, the corresponding subscriber group size management information published/instantiated to the subscriber group size information item by the RP 201 **(508)**. The sender NAP 205 may determine whether at least one subscriber is subscribed to the ICN identifier **(510)** based on the published subscriber group size management information. For example, if the published subscriber group size information indicates a subscriber group size other than zero/null, the NAP 205 determines that at least one subscriber is subscribed to the ICN identifier.

[0088] Responsive to determining that at least one subscriber is subscribed to the ICN identifier, then the sender NAP 205 may become the publisher for the IP packet and proceed with publishing the encapsulated IP packet towards such subscriber(s) in much the same way as described above **(512)**. If the NAP 205 does not determine that at least one subscriber is subscribed to the ICN identifier, then the NAP 205 may (e.g., immediately) drop the IP packet and/or issue a timeout error notification **(514)**.

[0089] As an alternative to determining whether at least one subscriber is subscribed to the ICN identifier in **(510)**, the NAP 205 may instead determine its corollary, namely, whether no subscriber is subscribed to the ICN identifier. For example, if the published subscriber group size information indicates a subscriber group size that is zero/null, the NAP 205 determines that no subscriber is subscribed to the ICN identifier. In this embodiment, the NAP 205 may (e.g., immediately) drop the IP packet and/or issue a timeout error notification responsive to determining that no subscriber is subscribed to the ICN identifier. If the NAP 205 does not determine that no subscriber is subscribed to the ICN identifier, then the sender NAP 205 may become the publisher for the IP packet and proceed with publishing the encapsulated IP packet towards subscriber(s) in much the same way as described above.

[0090] By performing a check as to whether at least one subscriber, or no subscriber, is subscribed to the ICN identifier (e.g., based on a quantity of subscribers to the ICN identifier), blocking may be avoided, response time may be shortened and bandwidth wastage may be

avoided as compared to standard IP networks (given that in standard IP networks, the IP packet would be forwarded in the network until arriving at an appropriate router for a subnet of the receiver address, which router, in turn, dismisses the IP packet).

[0091] *QoS-based ICN Transmission*

[0092] Figure 6 is a flow diagram illustrating an example procedure 600 implementing quality of service (QoS) based ICN transmissions. For simplicity of exposition, the procedure 600 is described with reference to the ICN system 200 of Figure 2. The procedure 600 may be carried out in other systems, as well.

[0093] The TM 203 may receive a request from the RP 201 to provide suitable resources for a publication/subscription match for an information item, *CID* (**602**). The request from the RP 201 may operate as a trigger to perform various ICN actions to accommodate the ICN pub/sub paradigm. For example, the TM may be triggered to examine various network layer information for path creation, and to create the path.

[0094] Before under taking such actions, the TM 203 may subscribe to a particular QoS expectation (or requirement) published by a content owner or a publisher for the information item, *CID*, under its respective management information item in the namespace 302 (Figure 3), the namespace 400 (Figure 4) or other like-type namespace(**604**). After receiving the QoS information (**606**), which can be encoded using any standard or non-standard based format, the TM 203 may carry out path creation suitably taking into account the QoS information (**608**), e.g., by selecting appropriately delay constrained routes in the network.

[0095] *Information Update Scheduling*

[0096] Figure 7 is a flow diagram illustrating an example procedure 700 implementing information update scheduling in an ICN system. For simplicity of exposition, the procedure 700 is described with reference to the ICN system 200 of Figure 2. The procedure 700 may be carried out in other systems, as well.

[0097] The number of subscribers may be used to determine an appropriate moment/time for updating information pertaining to an information item, *CID*. To facilitate this, the publisher for an information item, *CID*, may subscribe to the associated subscriber group size management information (**702**), and in response, may receive the subscriber group size (**704**).

[0098] Upon or after reaching a certain size (or a given increase in size) as compared to a previous value for this size (**706**), the publisher may update the information for information item, *CID*, with its current value (**708**). Using the current value of the information item, *CID*, a rate limitation may be implemented. This rate limitation, for example, may limit sending updates until after a sufficient or other threshold number of new subscribers have joined.

[0099] Load Distribution

[0100] Figure 8 is a flow diagram illustrating an example procedure 800 implementing load distribution in an ICN system. For simplicity of exposition, the procedure 700 is described with reference to the ICN system 200 of Figure 2. The procedure 800 may be carried out in other systems, as well.

[0101] The number of subscribers may be used to determine an appropriate moment/time for adding publishers to an information exchange scenario. Consider, for example, a transfer of information under information item, *CID*, (e.g., a video), starting with one publisher for the information. Prospective other publishers may subscribe to the associated management information for subscriber group size for the information item, *CID* **(802)**, and in response, may receive the subscriber group size **(804)**. Upon or after satisfying (e.g., equaling, exceeding, falling below, etc.) a defined threshold **(806)**, another publisher may decide to publish the availability of the same information item, *CID* **(806)**, which in turn, may lead to a re-matching of publishers and subscribers at the RP 201, and lowering as a result a load experienced by the initial publisher **(810)**. This process may be repeated with different thresholds, e.g., in certain steps with assignments to other publishers. Examples where such embodiment could be used is in a video distribution where different servers (publishers) join the distribution according to pre-defined subscriber group sizes (e.g., one server per 10k users).

[0102] Load Regionalization

[0103] Geographic distribution of the subscribers may be used to enhance the load distribution example above by adding publishers in appropriate geographic regions according to a defined threshold. By doing so, the load on the publishers may be regionalized as the subscriber group grows.

[0104] Semantic mediation

[0105] The semantic management information may be used to convey a semantic baseline among the group of publishers and subscribers by having each publisher and subscriber subscribe to this management information and encode the transmitted information accordingly. Any change to the semantics (which could be published by any member of the publisher and subscriber group) may lead to a new encoding of the transmitted information according to the signaled semantic.

[0106] Incorporated herein by reference are:

[0107] V. Jacobson, "Networking named content", Proceedings of the 5th international conference on Emerging networking experiments and technologies, ACM CoNext, 2009;

[0108] D. Trossen, G. Parisi, Designing and Realizing An Information-Centric Internet, IEEE Communications Magazine Special Issue on "Information-centric Networking", July 2012; and

[0109] US Provisional Patent Application No. 62/063,746 (Attorney Docket No. 12312US01) filed 14-Oct-2014.

[0110] **Conclusion**

[0111] Although features and elements are provided above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations may be made without departing from its spirit and scope, as will be apparent to those skilled in the art. No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly provided as such. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods or systems.

[0112] It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting. As used herein, the term "video" may mean any of a snapshot, single image and/or multiple images displayed over a time basis. As another example, when referred to herein, the terms "user equipment" and its abbreviation "UE" may mean (i) a wireless transmit and/or receive unit (WTRU), such as described *supra*; (ii) any of a number of embodiments of a WTRU, such as described *supra*; (iii) a wireless-capable and/or wired-capable (e.g., tetherable) device configured with, *inter alia*, some or all structures and functionality of a WTRU, such as described *supra*; (iii) a wireless-capable and/or wired-capable device configured with less than all structures and functionality of a WTRU, such as described *supra*; or (iv) the like. Details of an example WTRU, which may be representative of any UE recited herein, are provided above with respect to Figures 1A-1C.

[0113] In addition, the methods provided herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-

readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

[0114] Variations of the method, apparatus and system provided above are possible without departing from the scope of the invention. In view of the wide variety of embodiments that can be applied, it should be understood that the illustrated embodiments are examples only, and should not be taken as limiting the scope of the following claims. For instance, the embodiments provided herein include handheld devices, which may include or be utilized with any appropriate voltage source, such as a battery and the like, providing any appropriate voltage.

[0115] Moreover, in the embodiments provided above, processing platforms, computing systems, controllers, and other devices containing processors are noted. These devices may contain at least one Central Processing Unit ("CPU") and memory. In accordance with the practices of persons skilled in the art of computer programming, reference to acts and symbolic representations of operations or instructions may be performed by the various CPUs and memories. Such acts and operations or instructions may be referred to as being "executed," "computer executed" or "CPU executed."

[0116] One of ordinary skill in the art will appreciate that the acts and symbolically represented operations or instructions include the manipulation of electrical signals by the CPU. An electrical system represents data bits that can cause a resulting transformation or reduction of the electrical signals and the maintenance of data bits at memory locations in a memory system to thereby reconfigure or otherwise alter the CPU's operation, as well as other processing of signals. The memory locations where data bits are maintained are physical locations that have particular electrical, magnetic, optical, or organic properties corresponding to or representative of the data bits. It should be understood that the embodiments are not limited to the above-mentioned platforms or CPUs and that other platforms and CPUs may support the provided methods.

[0117] The data bits may also be maintained on a computer readable medium including magnetic disks, optical disks, and any other volatile (e.g., Random Access Memory (RAM)) or non-volatile (e.g., Read-Only Memory (ROM)) mass storage system readable by the CPU. The computer readable medium may include cooperating or interconnected computer readable medium, which exist exclusively on the processing system or are distributed among multiple interconnected processing systems that may be local or remote to the processing system. It

should be understood that the embodiments are not limited to the above-mentioned memories and that other platforms and memories may support the provided methods.

[0118] In an illustrative embodiment, any of the operations, processes, etc. described herein may be implemented as computer-readable instructions stored on a computer-readable medium. The computer-readable instructions may be executed by a processor of a mobile unit, a network element, and/or any other computing device.

[0119] There is little distinction left between hardware and software implementations of aspects of systems. The use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software may become significant) a design choice representing cost versus efficiency tradeoffs. There may be various vehicles by which processes and/or systems and/or other technologies described herein may be effected (e.g., hardware, software, and/or firmware), and the preferred vehicle may vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle. If flexibility is paramount, the implementer may opt for a mainly software implementation. Alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

[0120] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples may be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In an embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), and/or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, may be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter

described herein may be distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a CD, a DVD, a digital tape, a computer memory, etc., and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[0121] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein may be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system may generally include one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity, control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0122] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality may be achieved. Hence, any two components herein combined to achieve a particular functionality may be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated may also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated may also be viewed as being "operably couplable" to each other to achieve

the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0123] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0124] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, where only one item is intended, the term "single" or similar language may be used. As an aid to understanding, the following appended claims and/or the descriptions herein may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"). The same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense

one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B." Further, the terms "any of" followed by a listing of a plurality of items and/or a plurality of categories of items, as used herein, are intended to include "any of," "any combination of," "any multiple of," and/or "any combination of multiples of" the items and/or the categories of items, individually or in conjunction with other items and/or other categories of items. Moreover, as used herein, the term "set" is intended to include any number of items, including zero. Additionally, as used herein, the term "number" is intended to include any number, including zero.

[0125] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0126] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein may be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," "greater than," "less than," and the like includes the number recited and refers to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0127] Moreover, the claims should not be read as limited to the provided order or elements unless stated to that effect. In addition, use of the terms "means for" in any claim is intended to invoke 35 U.S.C. §112, ¶ 6 or means-plus-function claim format, and any claim without the terms "means for" is not so intended.

CLAIMS

What is claimed is:

1. A method implemented in an information-centric networking (ICN) element, the method comprising:
 - receiving management information responsive to a subscription to a scope for the management information, wherein the scope is disposed within an information structure, and wherein the scope is algorithmically associated to an information item or to another scope for an information item; and
 - using the received management information in connection with carrying out an ICN action.
2. The method of claim 1, wherein using the received management information comprises: using the received management information in connection with carrying out an operation ancillary to transmission of the information item.
3. The method of claim 1, wherein the received management information comprises subscriber group size information, and wherein using the received management information comprises:
 - on condition that the subscriber group size information indicates a non-zero number of subscribers, publishing an encapsulated internet protocol (IP) packet to an ICN identifier mapped to an IP address of the IP packet, wherein the encapsulated IP packet is published from a sender network attachment point (NAP) towards a receiver NAP that subscribed to the ICN identifier; and
 - on condition that the subscriber group size information indicates zero subscribers, dropping the IP packet and/or issuing a timeout error notification.
4. The method of claim 1, wherein the received management information comprises subscriber group size information, and wherein using the received management information comprises:
 - determining an ICN identifier representative of a destination internet protocol (IP) address of an IP packet received at a network attachment point;
 - determining, based on the subscriber group size information, whether at least one subscriber is subscribed to the ICN identifier;
 - responsive to determining that at least one subscriber is subscribed to the ICN identifier, encapsulating the IP packet in ICN headers for forwarding to the at least one subscriber, and publishing the encapsulated IP packet towards the at least one subscriber; and
 - responsive to determining that at least one subscriber is not subscribed to the ICN identifier, dropping the IP packet and/or issuing a timeout error notification.

5. The method of claim 1, wherein the received management information comprises subscriber group size information, the method further comprising:
determining an appropriate time to update the information item with a current value.
6. The method of claim 5, further comprising: updating the information item at the determined time.
7. The method of claim 1, wherein the received management information comprises subscriber group size information, the method further comprising:
updating the information item with a current value on condition that a subscriber group size indicated by the subscriber group size information satisfies a threshold number of subscribers,.
8. The method of claim 7, further comprising: implementing a rate for scheduling an update to the information item based, at least in part, on the current value.
9. The method of claim 1, wherein the received management information comprises quality-of-service (QoS) information, and wherein using the received management information comprises using the received QoS information in connection with carrying out path creation for transmission of the information item.
10. The method of claim 1, wherein the received management information comprises quality-of-service (QoS) information, and wherein using the received management information comprises using the received QoS information to assemble suitable communications resources for transmission of the information item.
11. The method of claim 1, wherein the received management information comprises state information, using the received management information comprises:
sending an update to the information item based on the state information
12. The method of claim 1, wherein the received management information comprises any of subscriber group size information and publisher group size information, and wherein using the received management information comprises:
using any of the received subscriber group size information and publisher group size information to determine an appropriate time to join as a publisher to an information exchange.
13. The method of claim 12, wherein the appropriate time is determined based on any of (i) a subscriber group size indicated by the subscriber group size information satisfying a threshold

number of subscribers; and (ii) a publisher group size indicated by the publisher group size information satisfying a threshold number of publishers.

14. The method of claim 1, wherein the received management information comprises geographic distribution information, using the received management information comprises:

adding one or more publishers in appropriate geographic regions based on the geographic distribution information.

15. The method of claim 1, wherein the received management information comprises semantic management information, using the received management information comprises:

using semantic management information to convey a semantic baseline among a group of publishers and subscribers by having each publisher and subscriber subscribe to the semantic management information and encode the transmitted information accordingly.

16. An information-centric networking (ICN) element comprising circuitry, including a processor and a memory storing instructions executable by the processor, configured to:

receive management information responsive to a subscription to a scope for the management information, wherein the scope is disposed within an information structure, and wherein the scope is algorithmically associated to an information item or to another scope for an information item; and

use the received management information in connection with carrying out an ICN action.

17. The ICN element of claim 16, wherein the circuitry is configured to use the received management information in connection with carrying out an operation ancillary to transmission of the information item.

18. The ICN element of claim 16, wherein the received management information comprises subscriber group size information, and wherein the circuitry is configured to:

on condition that the subscriber group size information indicates a non-zero number of subscribers, publish an encapsulated internet protocol (IP) packet to an ICN identifier mapped to an IP address of the IP packet, wherein the encapsulated IP packet is published towards a network attachment point (NAP) that subscribed to the ICN identifier; and

on condition that the subscriber group size information indicates zero subscribers, drop the IP packet and/or issue a timeout error notification.

19. The ICN element of claim 16, wherein the received management information comprises subscriber group size information, and wherein the circuitry is configured to:

receive an IP packet;

determine an ICN identifier representative of a destination internet protocol (IP) address of the received IP packet;

determine, based on the subscriber group size information, whether at least one subscriber is subscribed to the ICN identifier;

responsive to determining that at least one subscriber is subscribed to the ICN identifier, encapsulate the IP packet in ICN headers for forwarding to the at least one subscriber, and publish the encapsulated IP packet towards the at least one subscriber; and

responsive to determining that at least one subscriber is not subscribed to the ICN identifier, drop the IP packet and/or issue a timeout error notification.

20. The ICN element of any of the claims 16-19, wherein the ICN element comprises a network attachment point.

21. The ICN element of claim 16, wherein the received management information comprises subscriber group size information, and wherein the circuitry is configured to determine an appropriate time to update the information item with a current value.

22. The ICN element of claim 21, wherein the circuitry is configured to update the information item at the determined time.

23. The ICN element of claim 16, wherein the received management information comprises subscriber group size information, and wherein the circuitry is configured to update the information item with a current value on condition that a subscriber group size indicated by the subscriber group size information satisfies a threshold number of subscribers.

24. The ICN element of claim 23, wherein the circuitry is configured to implement a rate for scheduling an update to the information item based, at least in part, on the current value.

25. The ICN element of claim 16, wherein the received management information comprises state information, and wherein the circuitry is configured to send an update to the information item based on the state information

26. The ICN element of claim 16, wherein the received management information comprises geographic distribution information, and wherein the circuitry is configured to rejoin as a publisher in an appropriate geographic region based on the geographic distribution information.

27. The ICN element of any of the claims 16 and 21-26, wherein the ICN element comprises a current publisher for the information item.

28. The ICN element of claim 16, wherein the received management information comprises quality-of-service (QoS) information, and wherein the circuitry is configured to using the

received QoS information in connection with carrying out path creation for transmission of the information item.

29. The ICN element of claim 16, wherein the received management information comprises quality-of-service (QoS) information, and wherein the circuitry is configured to use the received QoS information to assemble suitable communications resources for transmission of the information item.

30. The ICN element of any of the claims 16 and 28-29, wherein the ICN element comprises a topology manager.

31. The ICN element of claim 16, wherein the received management information comprises any of subscriber group size information and publisher group size information, and wherein the circuitry is configured to use any of the received subscriber group size information and publisher group size information to determine an appropriate time to join as a publisher to an information exchange.

32. The ICN element of claim 31, wherein the appropriate time is determined based on any of (i) a subscriber group size indicated by the subscriber group size information satisfying a threshold number of subscribers; and (ii) a publisher group size indicated by the publisher group size information satisfying a threshold number of publishers.

33. The ICN element of claim 16, wherein the received management information comprises geographic distribution information, and wherein the circuitry is configured to join as a publisher in an appropriate geographic region based on the geographic distribution information.

34. The ICN element of any of the claims 16 and 31-33, wherein the ICN element comprises a new publisher for the information item.

35. The ICN element of claim 16, wherein the received management information comprises semantic management information that defines a semantic baseline, and wherein the circuitry is configured to use the semantic baseline to encode information for transmission.

36. The ICN element of any of the claims 16 and 35, wherein the ICN element comprises a publisher for the information item.

37. The ICN element of claim 16, wherein the received management information comprises semantic management information that defines a semantic baseline, and wherein the circuitry is configured to use the semantic baseline to decode received information.

38. The ICN element of any of the claims 16 and 37, wherein the ICN element comprises a subscriber to the information item.
39. A method implemented in an information centric networking (ICN) element, the method comprising:
- establishing, within an information structure, a scope for management information, wherein the scope is algorithmically associated to an information item or to another scope for an information item; and
 - incorporating management information within the information structure in connection with the scope for management information.
40. The method of claim 39, wherein the information item and the other scope are within the information structure.
41. The method of claim 39, wherein the information item and the other scope are within a different information structure.
42. The method of claim 41, wherein the different information structure comprises a directed acyclic graph (DAG) structure that includes the information item and the other scope.
43. The method of any of the claims 39-42, wherein the information structure comprises a directed acyclic graph (DAG) structure that includes the scope for management information.
44. The method of any of the claims 39-43, wherein an identifier is used in the information structure to represent an item of the management information.
45. An information-centric networking (ICN) element comprising circuitry, including a processor and a memory storing instructions executable by the processor, configured to:
- establish, within an information structure, a scope for management information, wherein the scope is algorithmically associated to an information item or to another scope for an information item; and
 - incorporating management information within the information structure in connection with the scope for management information.
46. The ICN element of claim 45, wherein the information item and the other scope are within the information structure.
47. The ICN element of claim 45, wherein the information item and the other scope are within a different information structure.

48. The ICN element of claim 47, wherein the different information structure comprises a directed acyclic graph (DAG) structure that includes the information item and the other scope.
49. The ICN element of any of the claims 45-48, wherein the information structure comprises a directed acyclic graph (DAG) structure that includes the scope for management information.
50. The ICN element of any of the claims 45-49, wherein an identifier is used in the information structure to represent an item of the management information.
51. The ICN element of any of the claims 45-50, wherein the ICN element comprises a rendezvous point.
52. A method implemented in an information-centric networking (ICN) element, the method comprising:
- establishing a root of a management information namespace by encoding a root of an information namespace;
 - incorporating, under the root of the management information namespace, a replica of an information structure disposed under the root of the information namespace; and
 - incorporating management information associated to an incorporated scope and/or information item under such scope and/or information item.
53. The method of claim 52, wherein the management information namespace defines a directed acyclic graph (DAG) structure.
54. The method of any of claims 52-53, wherein the information namespace defines a directed acyclic graph (DAG) structure.
55. The method of any of the claims 52-54, further comprising: performing a collision avoidance procedure on the management information to avoid incorporating a colliding identifier.
56. An information-centric networking (ICN) element comprising circuitry, including a processor and a memory storing instructions executable by the processor, configured to:
- establish a root of a management information namespace by encoding a root of an information namespace;
 - incorporate, under the root of the management information namespace, a replica of an information structure disposed under the root of the information namespace; and
 - incorporate management information associated to an incorporated scope and/or information item under such scope and/or information item.

57. The ICN element of claim 56, wherein the management information namespace defines a directed acyclic graph (DAG) structure.
58. The ICN element of any of claims 56-57, wherein the information namespace defines a directed acyclic graph (DAG) structure.
59. The ICN element of any of the claims 56-58, wherein the circuitry is configured to perform a collision avoidance procedure on the management information to avoid incorporating a colliding identifier.
60. A method implemented in an information-centric networking (ICN) element, the method comprising:
- establishing a management information item within an information namespace in connection with an information item or a scope of the information namespace; and
 - incorporating, under the management information item, management information associated to the information item and/or scope.
61. The method of claim 60, wherein the management information item defines a scope for management information.
62. The method of any of the claims 60-61, wherein the information namespace defines a directed acyclic graph (DAG) structure.
63. The method of any of the claims 60-62, further comprising: performing collision avoidance procedure on the management information item to avoid incorporating a colliding identifier.
64. An information-centric networking (ICN) element comprising circuitry, including a processor and a memory storing instructions executable by the processor, configured to:
- establish a management information item within an information namespace in connection with an information item or a scope of the information namespace; and
 - incorporate, under the management information item, management information associated to the information item and/or scope.
65. The ICN element of claim 64, wherein the management information item defines a scope for management information.
66. The ICN element of any of the claims 64-65, wherein the information namespace defines a directed acyclic graph (DAG) structure.

67. The ICN element of any of the claims 64-66, wherein the circuitry is configured to perform collision avoidance procedure on the management information item to avoid incorporating a colliding identifier.

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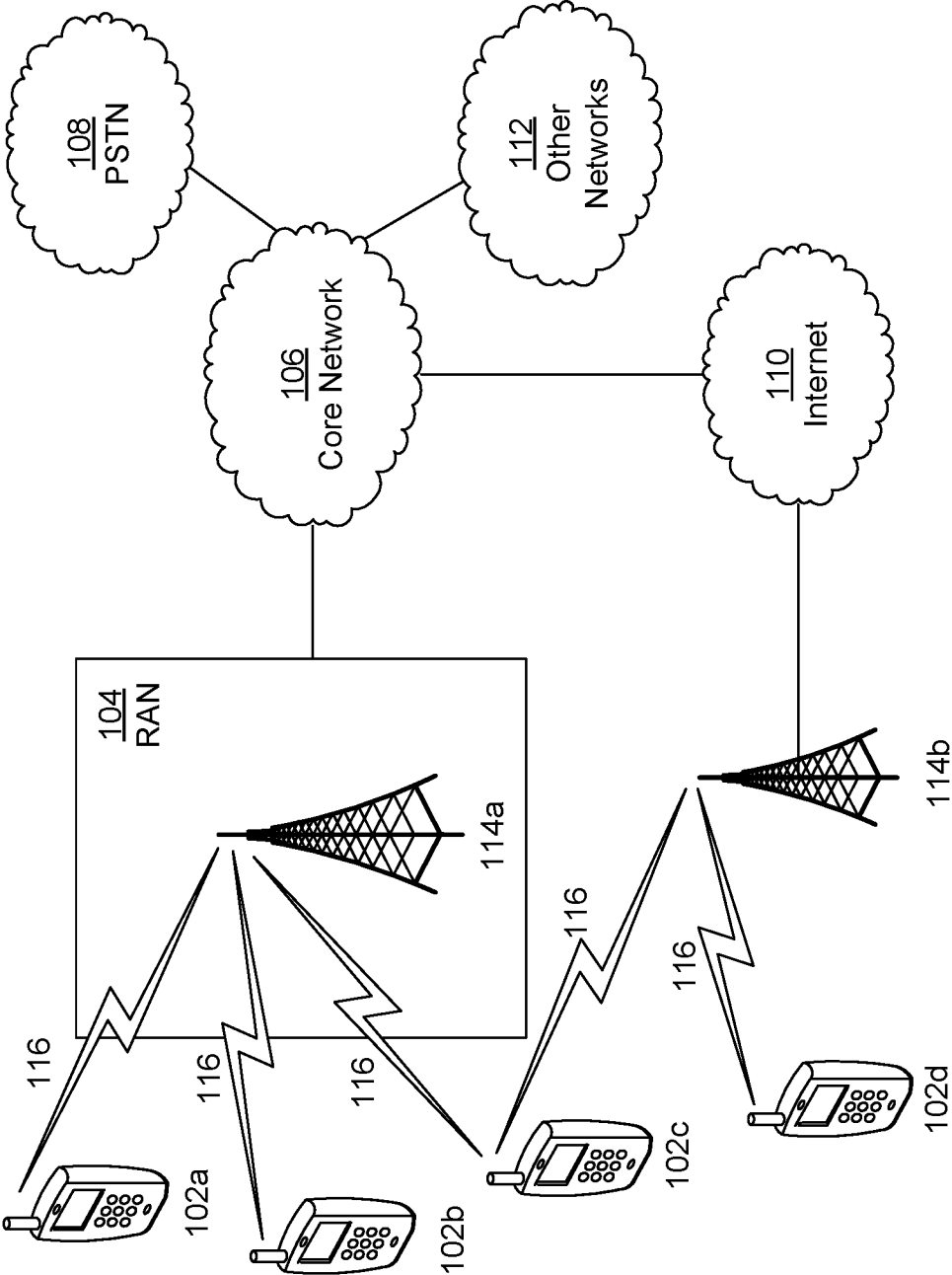
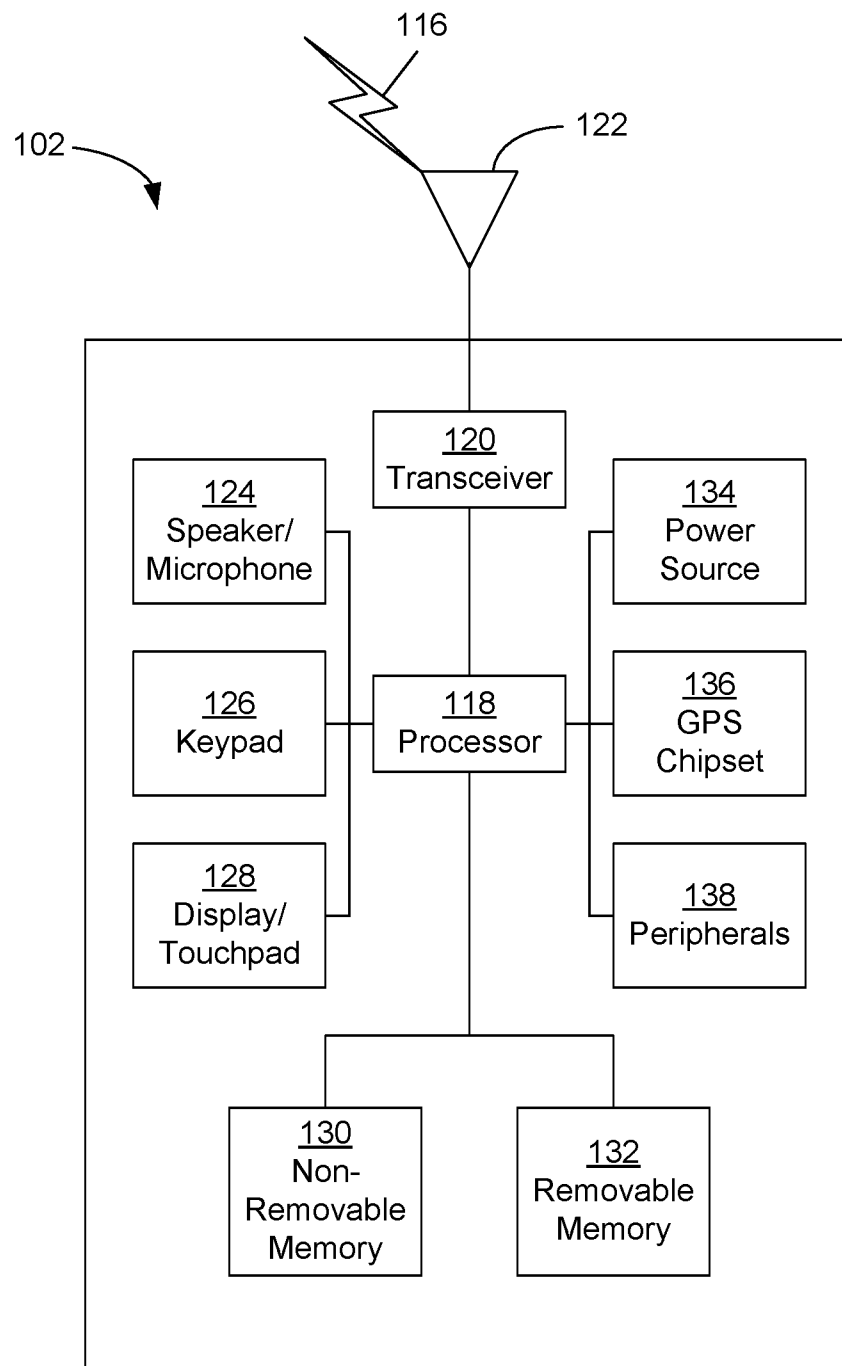


FIG. 1A

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**FIG. 1B**

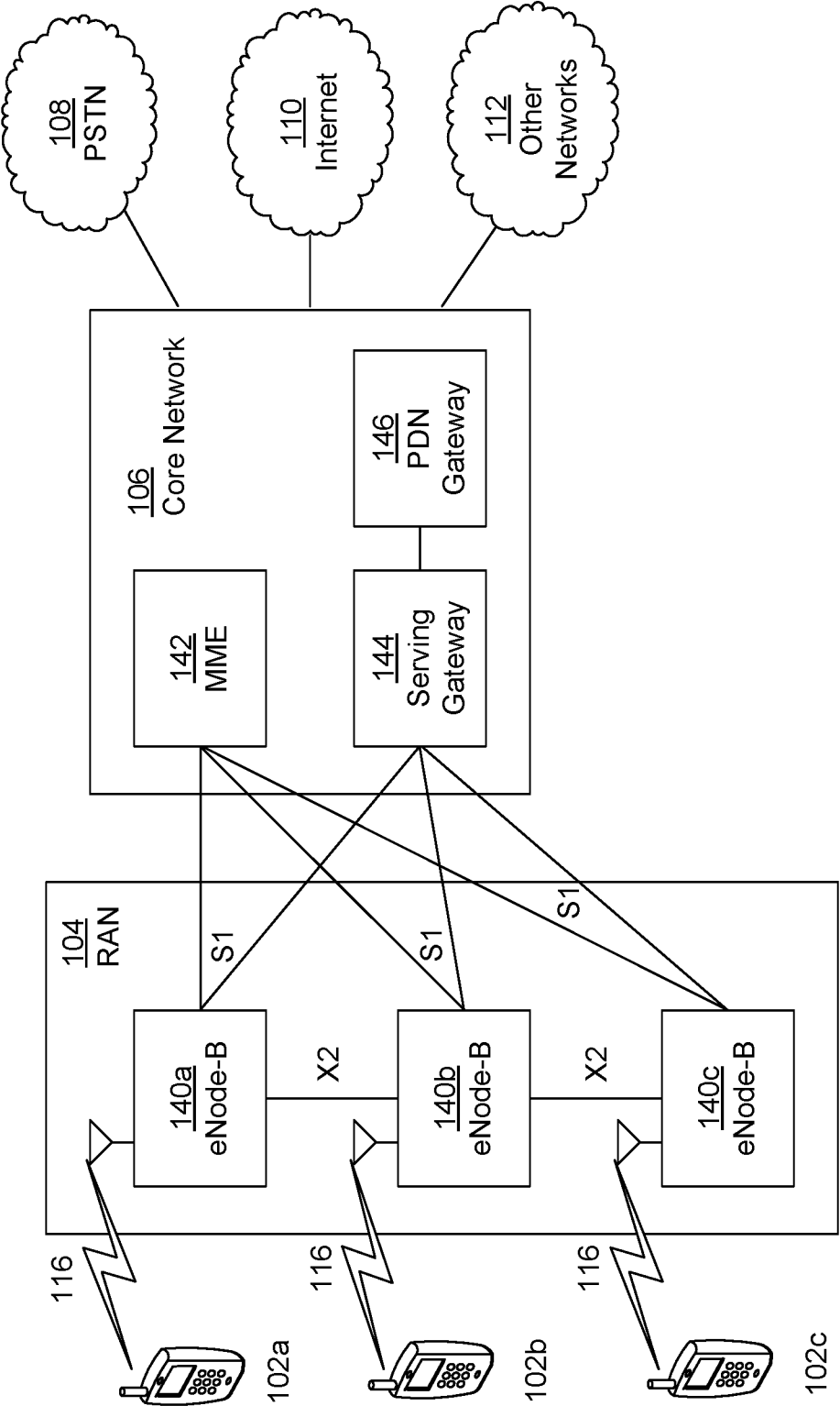


FIG. 1C

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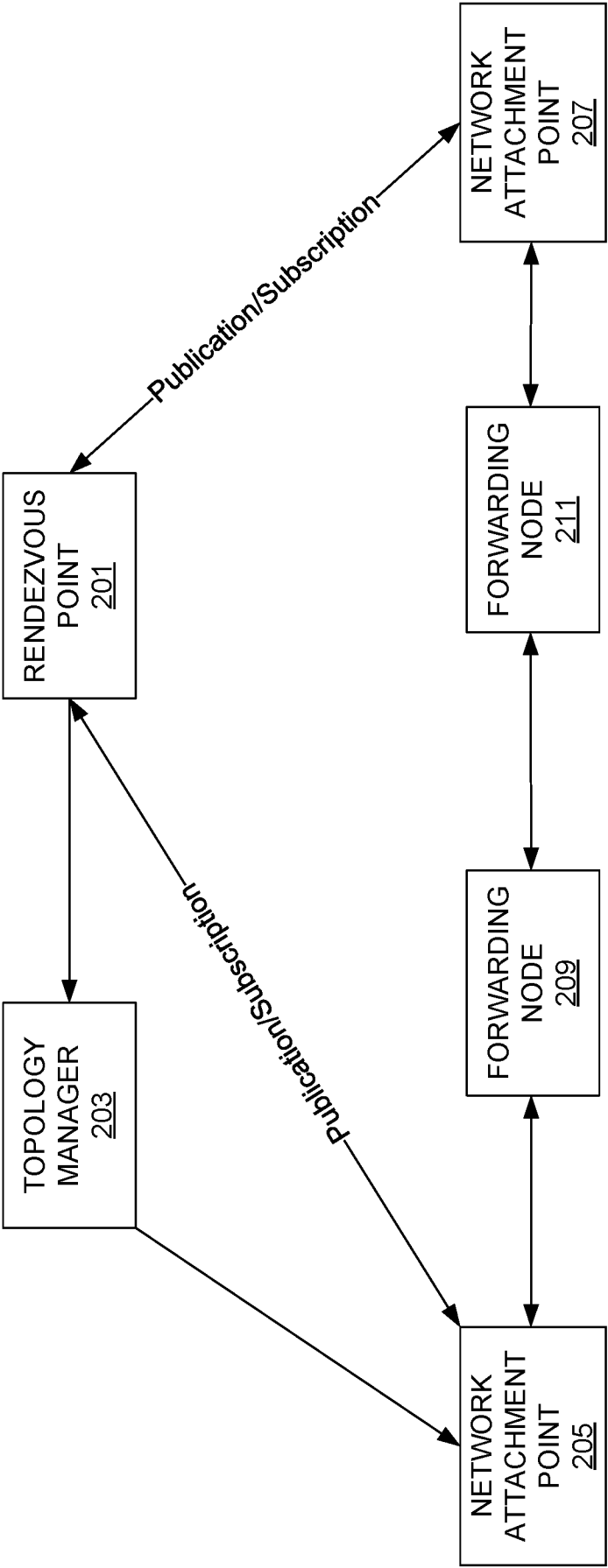


FIG. 2

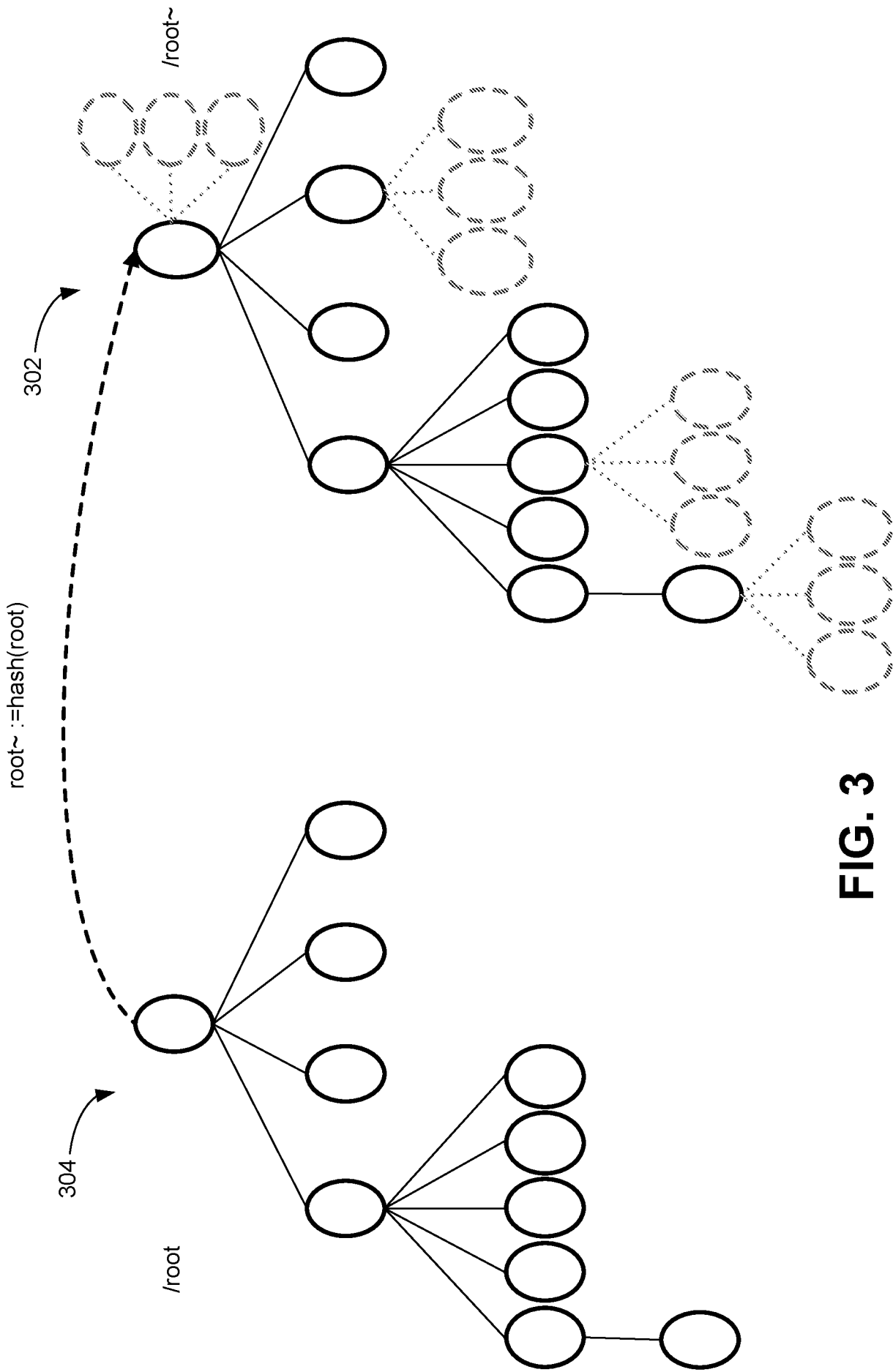


FIG. 3

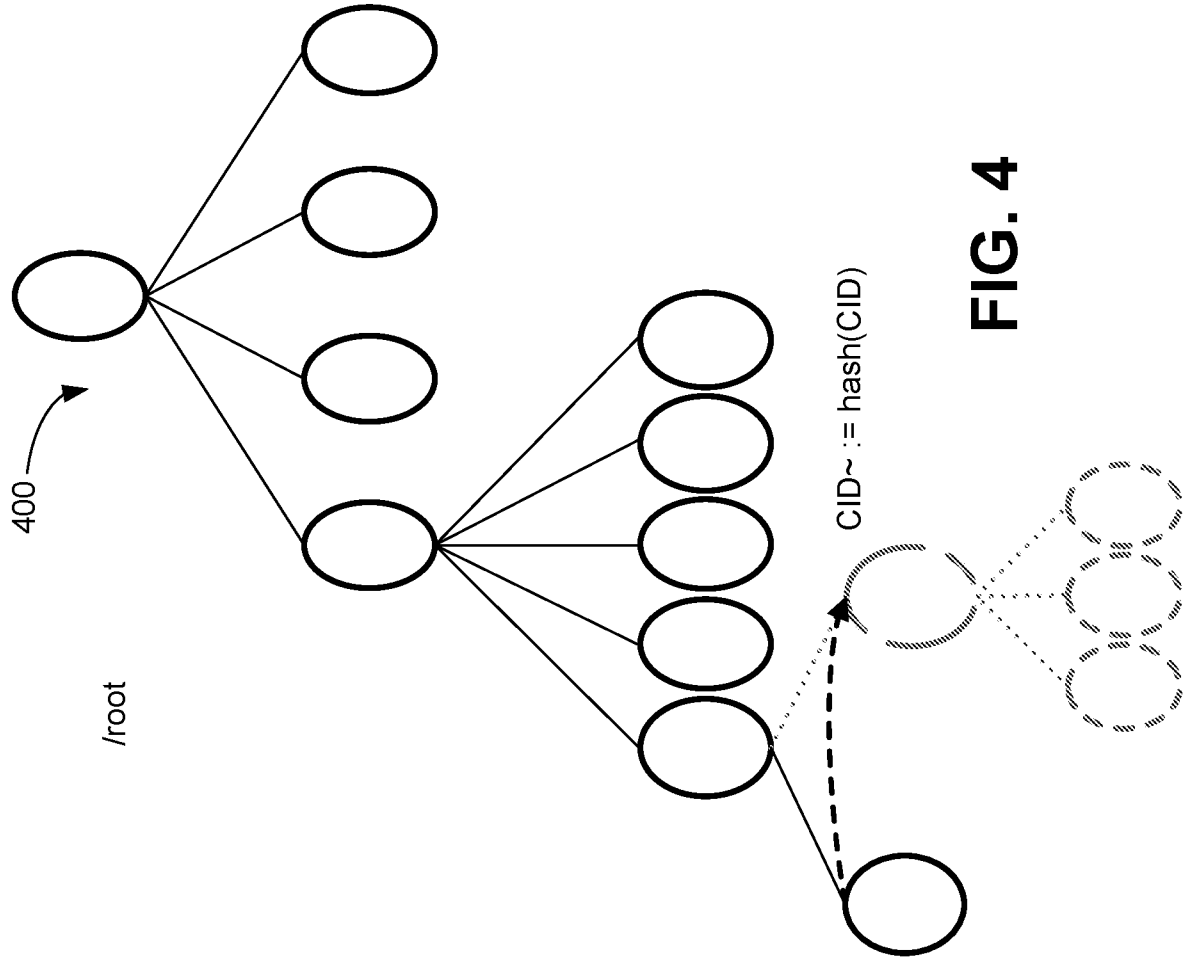


FIG. 4

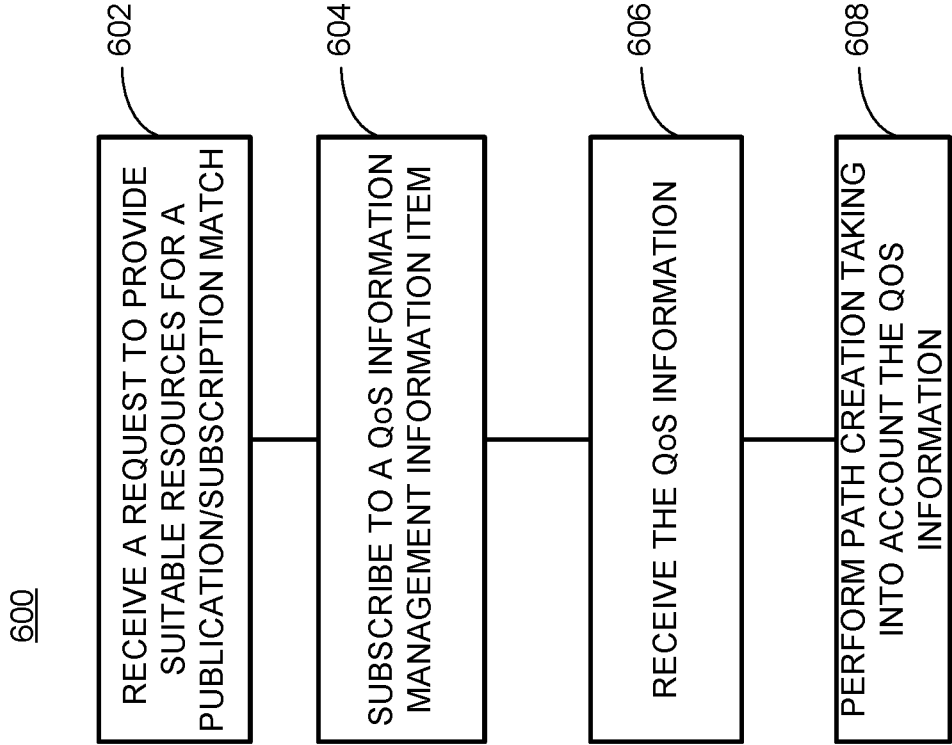
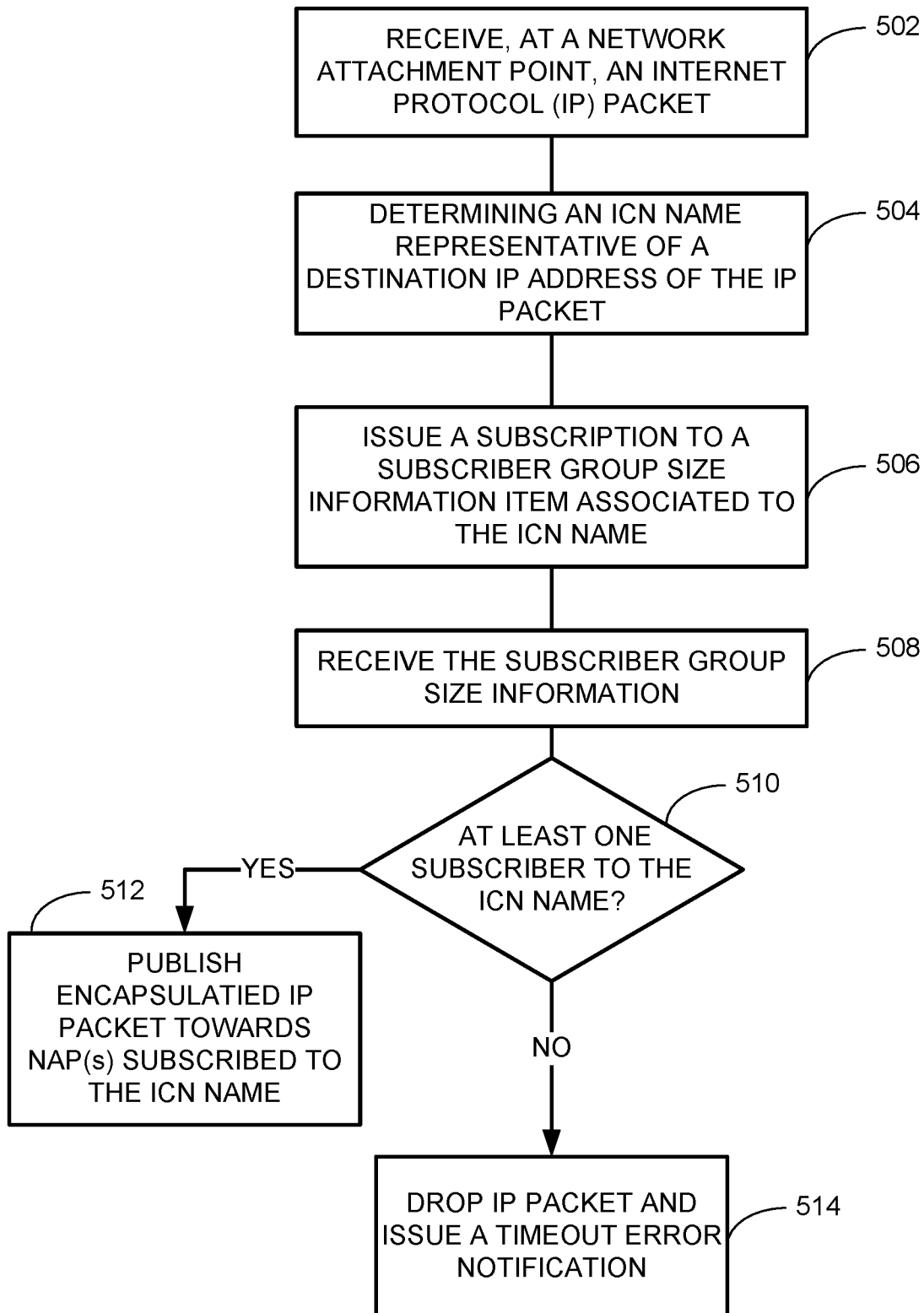
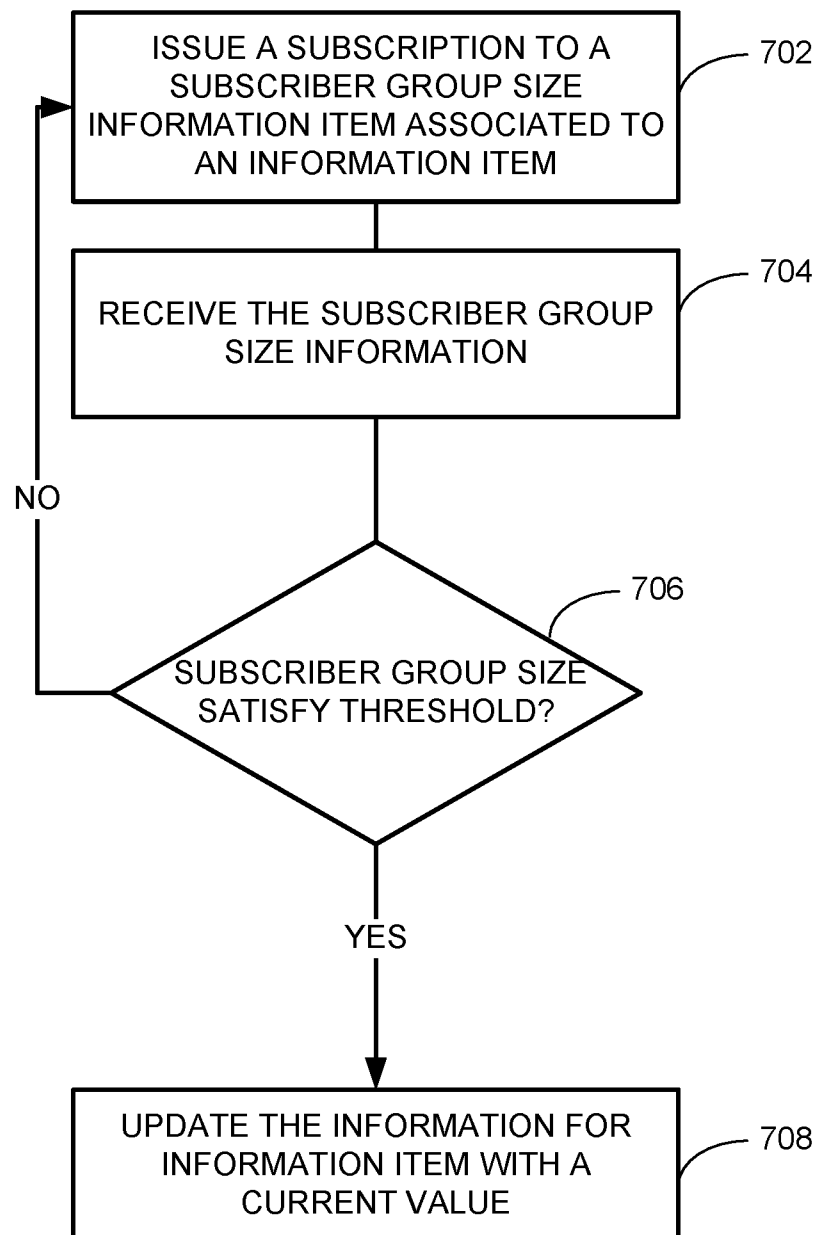


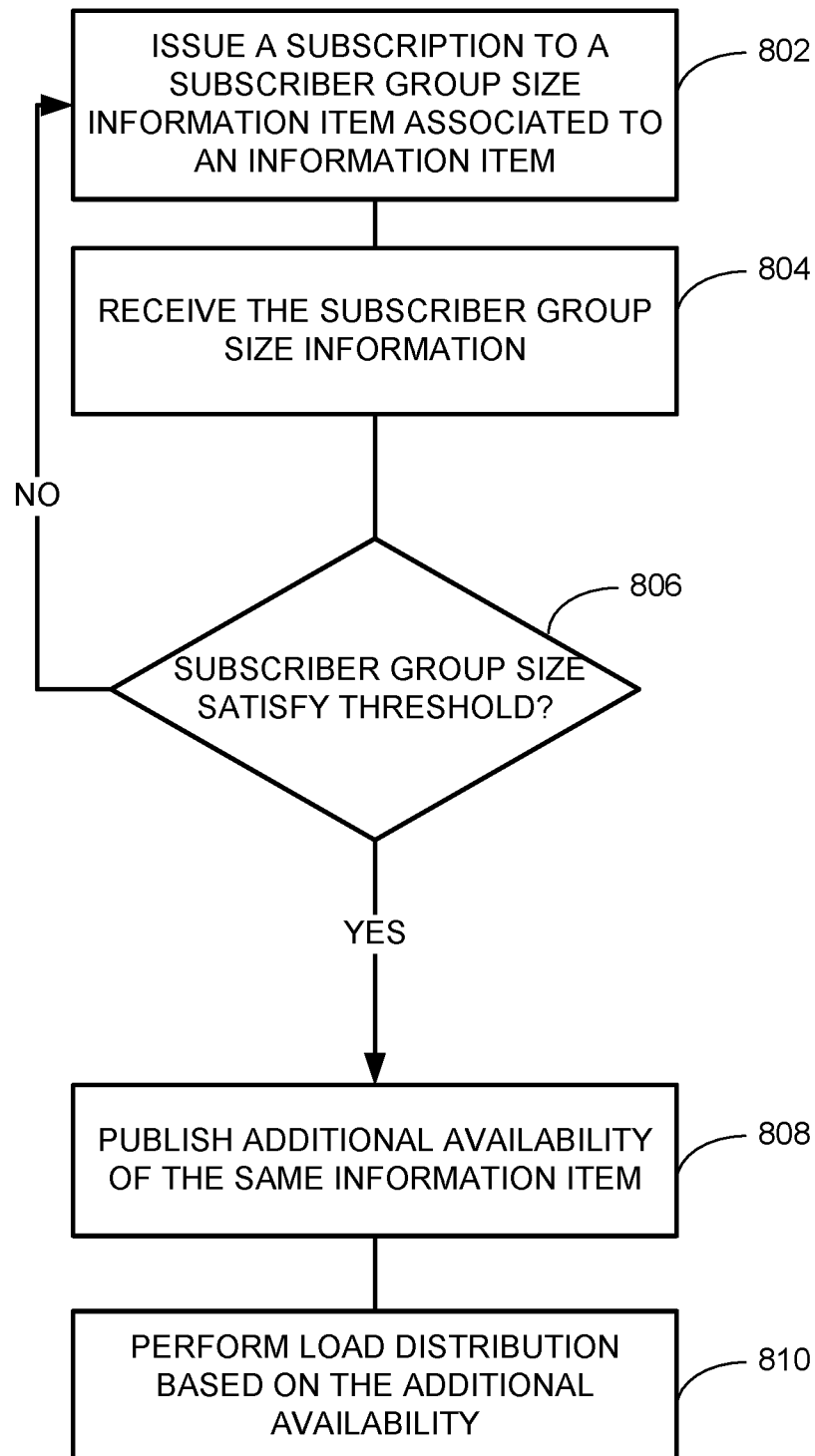
FIG. 6

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500**FIG. 5**

700**FIG. 7**

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800**FIG. 8**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/037121

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L29/08
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	D. TROSSEN; G. PARISIS: "Designing and Realizing An Information-Centric Internet", IEEE COMMUNICATIONS MAGAZINE SPECIAL, July 2012 (2012-07), XP011478261, cited in the application abstract page 64, left-hand column ----- -/--	1-67



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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"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

5 September 2016

Date of mailing of the international search report

09/09/2016

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Authorized officer

Suciu, Radu

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/037121

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CORUJO INSTITUTO DE TELECOMUNICACOES K PENTIKOUSIS EICT I VIDAL J GARCIA-REINOSO UC3M S LEDERER ALPEN-ADRIA UNIVERSITAT KLagenfurt: "ICN Management Considerations; draft-corujo-icn-mgmt-05.txt", ICN MANAGEMENT CONSIDERATIONS; DRAFT-CORUJO-ICN-MGMT-05.TXT, INTERNET ENGINEERING TASK FORCE, IETF; STANDARDWORKINGDRAFT, INTERNET SOCIETY (ISOC) 4, RUE DES FALAISES CH- 1205 GENEVA, SWITZERLAND, 1 July 2014 (2014-07-01), pages 1-18, XP015099919, [retrieved on 2014-07-01] abstract -----	1-67
A	BORISLAVA GAJIC ET AL: "On flexible topology formation in publish-subscribe networks", COMMUNICATIONS (ICC), 2012 IEEE INTERNATIONAL CONFERENCE ON, IEEE, 10 June 2012 (2012-06-10), pages 5804-5809, XP032274558, DOI: 10.1109/ICC.2012.6364732 ISBN: 978-1-4577-2052-9 abstract -----	1-67