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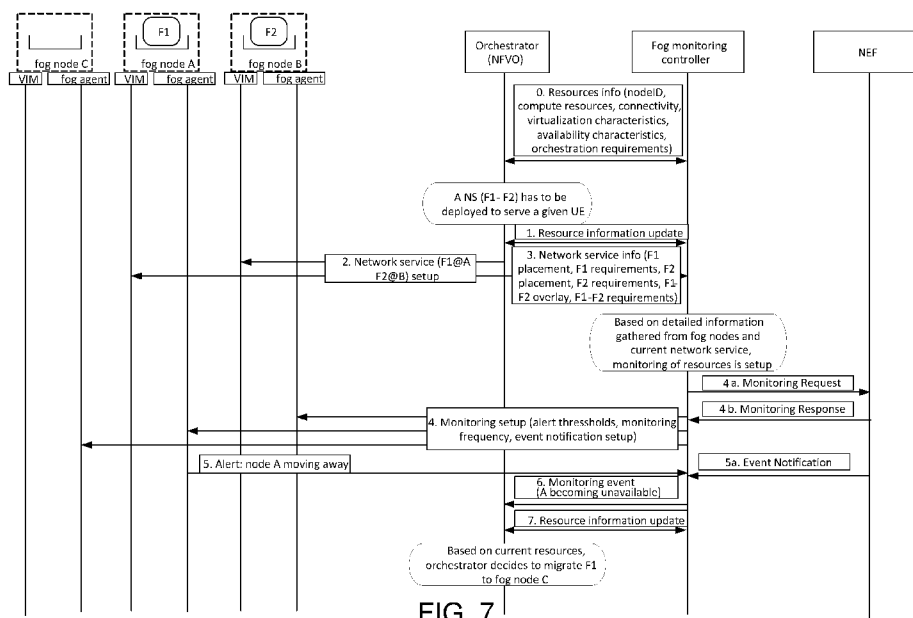


FIG. 7

(57) Abstract: Methods, procedures, architectures, apparatuses, systems, devices, interfaces, and computer program products for monitoring including autonomic set-up and registration of a Fog Monitoring Controller (FMC) and Fog Agents (FAs). A method includes receiving multicast advertisement messages (MAMs) advertising the FMC via an interface connecting the FMC and the FA, the MAMs including information indicating an identity (ID) of the FMC and a FMC scope associated with the FMC; transmitting multicast discovery messages (MDMs) including a fog node ID and a respective fog node scope associated with each fog node, the MDMs including information notifying the FMC about any number of resources associated with a fog node hosting the FA; receiving unicast advertisements including information indicating: an ID associated with the fog monitoring, the ID of the FMC, and the scope associated with the FMC; and transmitting unicast registration messages including information indicating that the FA is registered for fog monitoring.

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METHODS AND APPARATUSES FOR SUPPORTING RESOURCE MOBILITY AND VOLATILITY IN FOG ENVIRONMENTS

BACKGROUND

[0001] The present invention relates to the field of communications and, more particularly, to methods, apparatus, systems, architectures and interfaces for communications in an advanced or next generation wireless communication system, including communications carried out using a new radio and/or new radio (NR) access technology and communication systems.

[0002] With ongoing and increasing virtualization of networks, service functions (SFs), which may be interchangeably referred to as any of functions, network functions (NFs), services, network services, slices, network slices, or virtualized network functions (VNFs), are widely deployed and essential in many networks. SFs (e.g., network slices) provide a range of features, e.g., functions, such as security, WAN acceleration, and server load balancing, and may be instantiated at different points in a network, such as a base station, a core network entity, a data center, a wide area network (WAN), a radio access network (RAN), and even on mobile nodes. A SF may be hosted on and/or executed using any of computing, storage and networking resources, for example, resources of different points in the network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Furthermore, like reference numerals in the figures indicate like elements, and wherein:

[0004] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0005] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0006] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0007] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0008] FIG. 2 is a diagram illustrating an example scenario of a network service;

[0009] FIG. 3 is a diagram illustrating an example scenario of a network service;

[0010] FIG. 4 is a diagram illustrating a flow diagram according to embodiments;

[0011] FIG. 5 is a diagram illustrating logical components of a fog monitoring solution according to embodiments;

[0012] FIG. 6 is an exemplary diagram illustrating autonomic instantiation of a fog resource monitoring framework according to embodiments; and

[0013] FIG. 7 is a diagram illustrating network-service specific monitoring and orchestration according to embodiments.

EXAMPLE NETWORKS FOR IMPLEMENTATION OF THE EMBODIMENTS

[0014] FIG. 1A is a diagram illustrating 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), zero-tail unique-word DFT-Spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0015] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a RAN 104/113, a CN 106/115, 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, any of which may be referred to as a “station” and/or a “STA”, may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0016] The communications systems 100 may also include a base station 114a and/or 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 CN 106/115, the Internet 110, and/or the other 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 gNB, a NR NodeB, a site controller, an access point (AP), a wireless router, 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.

[0017] The base station 114a may be part of the RAN 104/113, 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 on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. 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 an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0018] 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, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0019] 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 104/113 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 115/116/117 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 (DL) Packet Access (HSDPA) and/or High-Speed UL Packet Access (HSUPA).

[0020] In an 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) and/or LTE-Advanced Pro (LTE-A Pro).

[0021] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using New Radio (NR).

[0022] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0023] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi)), 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.

[0024] The base station 114b in FIG. 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, an industrial facility, an air corridor (e.g., for use by drones), a roadway, 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 an 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, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 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 CN 106/115.

[0025] The RAN 104/113 may be in communication with the CN 106/115, 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. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106/115 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 FIG. 1A, it will be appreciated that the RAN 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing a NR radio technology, the CN 106/115 may also be in communication

with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0026] The CN 106/115 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the 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/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104/113 or a different RAT.

[0027] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., 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 FIG. 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.

[0028] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 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 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0029] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), 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 Arrays (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 FIG. 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.

[0030] 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 an 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/or 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.

[0031] Although the transmit/receive element 122 is depicted in FIG. 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.

[0032] 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 NR and IEEE 802.11, for example.

[0033] 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 130 and/or the removable memory 132. The non-removable memory 130 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).

[0034] 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.

[0035] 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.

[0036] 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 and/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, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors, the sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor; an altimeter, a light sensor, a touch sensor, a

magnetometer, a barometer, a gesture sensor, a biometric sensor, and/or a humidity sensor.

[0037] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and downlink (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the downlink (e.g., for reception)).

[0038] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an 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 CN 106.

[0039] 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/or receive wireless signals from, the WTRU 102a.

[0040] 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 UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0041] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (or PGW) 166. While each of the foregoing elements are depicted as part of the CN 106, it will be

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

[0042] 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 serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0043] 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 perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0044] The SGW 164 may 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.

[0045] The CN 106 may facilitate communications with other networks. For example, the CN 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 CN 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 CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0046] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0047] In representative embodiments, the other network 112 may be a WLAN.

[0048] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have an access or an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an “ad-hoc” mode of communication.

[0049] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0050] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0051] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0052] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications, such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0053] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may

depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode), transmitting to the AP, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0054] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0055] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0056] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0057] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The

WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0058] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0059] Each of the gNBs 180a, 180b, 180c 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 UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0060] The CN 115 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN) 185a, 185b. While each of the foregoing elements are depicted as part of the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0061] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different PDU sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for machine type communication (MTC) access, and/or the like. The AMF 162 may provide a control plane function for switching between the RAN 113 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0062] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0063] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N3 interface, 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. The UPF 184, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering downlink packets, providing mobility anchoring, and the like.

[0064] The CN 115 may facilitate communications with other networks. For example, the CN 115 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 115 and the PSTN

108. In addition, the CN 115 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local Data Network (DN) 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0065] In view of Figures 1A-1D, and the corresponding description of Figures 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-b, UPF 184a-b, SMF 183a-b, DN 185a-b, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0066] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or may performing testing using over-the-air wireless communications.

[0067] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

DETAILED DESCRIPTION

Service Function Chaining

[0068] As Service Functions (SFs) (which may be interchangeably referred to as any of functions, network functions (NF), services, slices, network slices, or virtualized network functions (VNFs)) are becoming more prevalent, for example, even in traditionally closed environments such as cellular networks, providers of such networks are embracing cloud native technology. In wireless networks, such as 5th Generation (5G) and/or 3rd Generation Partnership Project (3GPP)-based systems, SFs, that is, NF Services, may be accessed using internet protocols, such as HyperText Transfer Protocol (HTTP). A hosting environment (e.g., any number of instantiation points of a network) of a function may be referred to as a SF provider or network function virtualization instantiation point of presence (NFVI-PoP). A SF may be applied at any layer within the network protocol stack (network layer, transport layer, application layer, etc.).

[0069] The deployment model for SFs (e.g., NF services) may be such that traffic is steered through the SFs, wherever the SF may be deployed. As such, functions may not need to be deployed in the traffic path. For a given service (e.g., security, WAN acceleration, etc.), a view (e.g., an abstracted view, a group, a collection, etc.) of (e.g., required) SFs, and an order in which the SF are to be applied, may be referred to as any of a service function chain (SFC) or a network function (e.g., a network slice) forwarding graph (NF-FG). An SFC may be instantiated through a selection of (e.g., specific) SF instances (e.g., instantiations) on (e.g., specific) network nodes, for example, to form a service graph, which may be referred to as a SF path (SFP).

Fog Computing

[0070] Fog computing may refer to (e.g., may be considered to be or include) a set of any of services, features, and slices. Fog computing may provide solutions for handling data generated from end-user devices, for example, in the Internet of Things (IoT). The term fog may refer to any networked computational resource (e.g., disposed, configured, associated, etc.) between things (e.g., of the IoT) and a cloud. A fog node may be an infrastructure network node, such as an enhanced NodeB (eNB) or gNodeB (gNB), a base station (BS), an edge server, a customer premises equipment (CPE), or even a user equipment (UE) terminal node and/or a wireless transmit/receive unit (WTRU), such as a laptop, a smartphone, or a computing unit on-board a vehicle, robot or drone.

[0071] In fog computing, the functions composing (e.g., included in) an SFC may be hosted on resources that may be (e.g., are inherently) any of heterogeneous, volatile and mobile. That is, for example, such resources may appear and disappear (e.g., be available or unavailable), and the connectivity characteristics between these resources may also change dynamically. Current resource orchestration solutions are (e.g., inherently) reactive and static or semi-static. As such, there is a need for (e.g. new) orchestration solutions that cope with dynamic resource changes in any of runtime or ahead of time (e.g., in anticipation through prediction).

[0072] European Telecommunications Standards Institute (ETSI) Multi-access Edge Computing (MEC) provides (e.g., allows for) computation capabilities near end users, for example, via static substrates (e.g., data centers or servers) deployed at an edge (e.g., edge network/node). Fog computing further extends this approach to encompass and integrate the computational substrates (e.g., including resources) scattered further down the static edge, such as in mobile terminal devices, CPEs or local servers. Furthermore, in conventional ETSI MEC, there is a need (e.g., a problem, challenge, etc.) for solutions and/or features related to providing (e.g., enabling of) a MEC host in a moving (e.g., mobile, transient, temporary, etc.) node.

Autonomic Networking

[0073] Autonomic networking may refer to any of: self-management and/or self-managing characteristics (e.g., configuration, protection, healing, optimization, etc.) of distributed network elements, and adapting to unpredictable changes of networks, for example, while hiding intrinsic complexity from network operators and users. Such a definition of autonomic networking is provided by the autonomic networking integrated model approach (ANIMA) working group (WG) of the Internet Engineering Task Force (IETF). The ANIMA WG has identified/specified (e.g., a minimum set of specific, reusable) infrastructure components, for example, to support autonomic interactions between devices, and to specify the application of these components to (e.g., one or two elementary) use cases of general value.

[0074] The ANIMA WG has (e.g., developed) a protocol specification regarding discovery for autonomic nodes, negotiation for autonomic nodes, bootstrapping a trust infrastructure and specification of a separated Autonomic Control Plane. A (e.g., first) protocol specification of the ANIMA WG is GeneRic Autonomic Signaling Protocol

(GRASP). This protocol defines (e.g., some) mechanisms for autonomic devices to discover each other, to synchronize state with each other, and to negotiate parameters and resources directly with each other. Each device may run (e.g., execute, instantiate, etc.) an Autonomic Service Agent (ASA) supporting GRASP protocol. GRASP message headers and options may be transmitted in Concise Binary Object Representation (CBOR). GRASP messages (e.g., every/any GRASP message) may have the following pattern:

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grasp-message = (message .within message-structure) / noop-message
message-structure = [MESSAGE_TYPE, session-id, ?initiator,
                    *grasp-option]
MESSAGE_TYPE = 1..255
session-id = 0..4294967295 ;up to 32 bits
grasp-option = any

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A MESSAGE_TYPE indicates a type of the message and may define expected options.

[0075] FIG. 2 is a diagram illustrating an example scenario of a network service.

[0076] A network service (e.g., network slice) shown in FIG. 2 may be a robot network service, for example, including any number of robot drones. A robot device 201 may have a control application (e.g., navigation control) running in a fog network (which may be interchangeably referred to as a fog) away from the robot 201. The control application may be running as a network service (e.g., network slice) in the form of an SFC “F1-F2” (e.g., F1 may be in charge of identifying obstacles and F2 may make decisions on robot navigation).

[0077] Initially the function F1 may (e.g., is assumed to) be hosted at a fog node A (e.g., a WTRU, a smartphone, a tablet, etc.) and F2 at fog node B (e.g., a server, a cloud host, a storage node, etc.). At some time, fog node A may become unavailable, for example, due to any of low battery power, the WTRU moving away from a coverage of a robot (or vice versa), or the WTRU moving away of the service area that allows it to control the robot (or vice versa). In view of fog node A becoming unavailable (e.g., for any of the above reasons and/or any other situations resulting in fog resources becoming unavailable), there is a need to predict and/or identify (e.g., a need, a trigger, for) migrating/moving the function F1 to another node, such as fog node C. That is, there may be a case where the function F1 should (e.g., needs to) be migrated prior to the fog node

A (which may be an edge node) becoming no longer available and/or capable of providing the function F1.

[0078] In the case of 3GPP, a Network Exposure Function (NEF) allows a controller (e.g., a central controller, and/or any controller that is considered as and/or to be an application function (AF)) to subscribe to key network notification events, such as User Plane Function (UPF) relocation, and make decisions not only in real time, but ahead of time (e.g., in anticipation of real time events). However, such dynamic migration cannot be dealt with in (e.g., may not be handled and/or accommodated by) conventional orchestration solutions, which are rather reactive and static or semi-static. That is, in conventional orchestration solutions, resources may fail, but failure is an exceptional event that happens with low frequency, and only scaling actions are supported to react to service level agreement (SLA) related events. For example, existing frameworks and/or solutions for fog networking rely on monitoring platforms that react to resource failure events and ensure that negotiated SLAs are met.

[0079] However such orchestration solutions (e.g., for ensuring SLAs are met) are not designed to predict events that may (e.g., likely) happen in a volatile fog environment, such as events including any of resources moving away, resources becoming unavailable due to battery issues, or changes in availability of resources, for example, because of variations of (e.g., the use of) the local resources on (e.g., of or by) the nodes. Further, in some environments, such as volatile and extremely mobile environments, continuous monitoring and reporting of (e.g., every possible) parameter(s) on all nodes hosting resources may be unfeasible. That is, continuous monitoring and reporting of parameters may not scale and may consume many resources and overhead.

[0080] In view of the above discussed challenges of fog networks having volatile and mobile environments, prediction (e.g., for make-before-break operations/features) should be used (e.g., is needed) because pure reaction (e.g., break-before- make operations/features) may not be adequate for volatile and mobile environments. According to embodiments discussed hereinbelow, prediction may not be generic, and, for example, may depend on (e.g., the nature, type, characteristics, etc., of) any of: a network service, a network slice, a SFC, the functions of the SFC, the connectivity between the SFC functions, service-specific requirements, etc.

[0081] Further, monitoring may (e.g., need to) be setup differently on different nodes, for example, depending on (e.g., specifics of characteristics of) the network service (e.g.,

network slice). According to embodiments discussed hereinbelow, for example, in order to act proactively and/or predict what may need to be done, monitoring in volatile and/or mobile environments may involve (e.g., include) any of: (1) nodes (e.g., currently) hosting the resources running the network service (e.g., network slice, SFC hosting a function, etc.), and (2) other nodes, for example, which may be (e.g., potential) candidates to join (e.g., either in addition and/or in substitution to current) nodes (e.g., hosting the resources) for running the network service, for example, in accordance with the orchestration decisions.

[0082] Referring to FIG. 2, the fog node A (e.g., initially hosting function F1) may be out of or running out of battery, or it might be moving towards (e.g., away to) a new tracking area (TA), such as TA 1 having a TA identity TAI1. In TAI1, the fog node A may not be allowed to control the robot, and such may (e.g., should) be detected (e.g., determined, notified, checked, etc.) before the fog node A (e.g., actually) becomes unavailable. In such a case, the function F1 may be migrated (e.g., effectively, within a certain amount of time, etc.) to fog node C or another fog node capable of meeting F1's requirements, such as compute, networking, location, expected availability, and other such requirements.

[0083] Further, there is a need for predicting (e.g., the need for) such a migration and (e.g., already, preemptively) identifying a target fog node for instantiating (e.g., for locating) the function (e.g., that is migrated). Further, in order to predict such a need, there is a need for a monitoring solution that instructs: (1) fog nodes (e.g., each of fog nodes A and B) involved in a network service (e.g., network slice, SFC, etc.) and (2) neighboring fog node candidates (e.g., fog node C) for hosting function (F1), to monitor and report on metrics that are relevant for the network service, F1-F2, that is currently running.

[0084] FIG. 3 is a diagram illustrating an example scenario of a network service.

[0085] As shown in FIG. 3, a drone may use a network service composed of the chain of functions F1-F2-F3, wherein F1 runs on the drone itself (e.g., fog node A), F2 runs on another drone (e.g., fog node B) and F3 runs on a gNB disposed on the ground (e.g., fog node D).

[0086] For example, in FIG. 3, there may be a case where the network service is an autonomous video surveillance activity in which the drone may (e.g., need to) perform image recognition to decide where to go next. In such a case, the drone, fog node B,

hosting function F2 may become unavailable, for example, because it is called back to the base. Such an event should be (e.g., needs to) be predicted before fog node B is no longer within the connectivity range of fog node A. Such a case shows the need for an intelligent and proactive monitoring solution that allows prediction of events, such as those discussed above.

[0087] According to embodiments, fog monitoring may provide solutions to at least the problems discussed above, for example, in view of FIGs. 2 and 3. According to embodiments discussed below, fog monitoring may provide solutions to any of (e.g., the problems of): (1) autonomic configuration (e.g., setting up) of monitoring agents; and (2) monitoring, detecting, and predicting fog-specific events.

[0088] According to embodiments, fog monitoring may include and/or allow for (e.g., fog) monitoring agents (e.g., to be) set-up in an autonomic way in the fog. According to embodiments, fog monitoring agents may be set-up autonomically, for example, according to any of monitoring requirements, configurations, parameters, for example, associated with any of what is needed and/or relevant to performing monitoring, for example, at a particular time, at each particular node, and for a particular network service/service function chain.

[0089] According to embodiments, fog monitoring may allow for monitoring, detecting, and predicting of fog-specific events impacting any of: the availability of resources, (e.g., related to mobility, such as anchor point relocation or allowable tracking area change), battery, local use of resources, environment, etc. According to embodiments, such fog monitoring may allow for (e.g., provide, enable, etc.) a make-before-break approach, for example, enabling the orchestration logic to take actions before a potentially disruptive event happens. According to embodiments, such fog monitoring may involve computing what may (e.g., is and/or needs to) be monitored, and how and on which nodes such may be computed (e.g., determined, identified, etc.). For example, such nodes may include any of nodes that are currently running the service functions and (e.g., also) other nodes, for example, which are candidates for joining the running of the network service, either in addition to and/or substitution to current nodes, for example, based on the orchestration logic decisions.

[0090] According to embodiments, fog monitoring, which may be interchangeably referred to as a fog monitoring solution, may be for (e.g., in charge of) monitoring and predicting the status of fog resources. According to embodiments, a fog monitoring

solution may be logically decoupled from Management and Orchestration (MANO). According to embodiments, a fog monitoring solution may interact with MANO (e.g., a MANO entity), for example, to notify the MANO (e.g., the MANO entity) about events, such as predicted events that may result in (e.g., require (e.g., need, trigger, necessitate, etc.) MANO actions (e.g. dynamic migration of functions).

[0091] According to embodiments, a fog monitoring solution may include any of: (1) a fog monitoring framework; (2) an interface towards a (e.g., 3GPP) NEF; and (3) autonomic and/or dynamic fog agent instantiation. According to embodiments, a fog monitoring framework may dynamically monitor (e.g., may be in charge of dynamically monitoring) a status of fog resources and may predict (e.g., may be in charge of predicting) a need for updating (e.g., running) services, for example according to the dynamic monitoring. According to embodiments, a fog monitoring framework may include any of: (1) distributed agents running (e.g., physically) on fog nodes; and (2) a (e.g., logically central) monitoring controller, for example, running elsewhere (e.g., at an infrastructure node and/or at a fog node). According to embodiments, any of network service and node-specific monitoring configurations may be performed on any (e.g., each) of the fog agents. For example, such configurations may be based on characteristics and/or requirements, such as those from (e.g., associated with) any of the network service (e.g., network slice) and/or SFC, which may be obtained from the MANO.

[0092] According to embodiments, performing (executing, contributing to, participating in, etc.) any of network service (e.g., network slice) specific and node-specific monitoring configurations on any (e.g., each) of the fog agents may include any of: discovering and deploying new fog agents, configuring monitoring actions on fog agents, receiving information (e.g., a current status) from the agents, and taking additional monitoring decisions based on a current status. According to embodiments, such operations and/or interactions may include (e.g., not be limited to) communications between the fog agent and the fog monitoring controller, and may (e.g., also) include (e.g., involve) interactions and/or actions occurring (e.g., directly, peer-to-peer, etc.) between two fog agents, for example, without the (e.g., direct) intervention of a fog monitoring controller. According to embodiments, monitored characteristics on fog nodes may include any of: available compute resources, battery power, mobility, etc. According to embodiments, monitoring may include (e.g., is not limited to) the nodes currently running the network service, and

may (e.g., also) include and/or involve other nodes, for example, which are candidates to join the running of the network service dependent on the MANO decisions.

[0093] According to embodiments, an interface towards a (e.g., 3GPP) NEF may be for requesting monitoring of events on (e.g., specific) fog nodes, for example, by providing identifiers of any of fog nodes and/or groups of fog nodes. Such identifiers may include a Generic Public Subscriber Identifier for any of an individual fog node or a group of fog nodes, such as a 5G LAN group identifier, a Virtual Data Network Name (VDNN), or any other similar and/or suitable 5G LAN group identifier, which may be globally unique.

[0094] According to embodiments, a fog monitoring solution may include a mechanism for dynamically and/or autonomically instantiating fog agents. For example, autonomic networking protocols, such as GRASP, may be used and/or extended to provide (e.g., required) functionality for dynamically and/or autonomically instantiating fog agents.

[0095] FIG. 4 is a diagram illustrating a flow diagram according to embodiments. FIG. 5 is a diagram illustrating logical components of a fog monitoring solution according to embodiments.

[0096] Referring to FIG. 4, an overall approach is depicted for the drone/robot features (e.g., use case) discussed with respect to FIGs. 2 and 3.

Fog Monitoring Framework

[0097] Fog environments may differ from data-center environments on at least three aspects, including heterogeneity, volatility and mobility. According to embodiments, a fog monitoring framework may be used to predict events, for example, that may trigger an orchestration event, such as migrating a function to a different resource.

[0098] Referring to FIGs. 4 and 5, a fog monitoring solution may include a fog monitoring framework having (e.g., two) logical components, including any of: (1) fog agent(s) (which may be interchangeably referred to as a fog monitoring agent (FMA)), and (2) a fog monitoring controller.

[0099] According to embodiments, a fog agent (e.g., FMA, running on each fog node) may send and/or receive (e.g., may be responsible for sending and/or receiving) information to and/or from any of a fog monitoring controller and other fog agents. According to embodiments, what to monitor (e.g., what is to be monitored) and what information to send (and, for example, a frequency for sending such information) may be configured per agent. According to embodiments, such a fog agent (e.g., FMA) may be

configured, for example, by considering the specifics of the network service and/or the SFC. According to embodiments, a fog agent may (e.g., also) take (e.g., some) autonomous actions. For example, a fog agent (e.g., FMA) may autonomously (e.g., autonomically) request migration of a function to a neighbor agent (e.g., a fog agent instantiated on a different node, or on a same node such that the node has more than one instantiated fog agent, one for each network slice) or node, for example, in a case where connectivity with the fog monitoring controller is (e.g., temporarily) unavailable.

[0100] According to embodiments, a fog monitoring controller may be run/running (e.g., executed/executing, operated/operating, instantiated, etc.) at any of an edge node or a fog node and may obtain input (e.g., receive signaling) from an orchestration logic (e.g., a MANO stack). The fog monitoring controller, according to embodiments, may autonomically (e.g., autonomously) decide (e.g., determine/select/identify a configuration for) what information to monitor. According to embodiments, a fog monitoring controller may (e.g., further) determine any of where and how to monitor such information, based on requirements, for example, as provided by the orchestration logic managing the network services instantiated in the fog. According to embodiments, such a configuration may be network service and/or function specific.

[0101] According to embodiments, a fog monitoring controller may interact with an orchestration logic, for example, to coordinate and/or trigger orchestration events, such as function migration, connectivity updates, etc. According to embodiments, in some deployments, a fog monitoring controller may be co-located with the orchestration logic (e.g., the NFVO).

[0102] According to embodiments, a fog monitoring controller may interact with fog agents, for example, to instruct (e.g., signal, command, etc.) fog agents regarding any of information and parameters (e.g., that need) to be monitored, and/or to obtain such information. According to embodiments, such interaction may include any of: fog agents at nodes currently involved in a given network service and/or SFC, and (e.g., other fog) nodes suitable for hosting a function (e.g., that needs) to be migrated. This allows a fog monitoring controller to provide the orchestration logic with candidate (e.g., fog) nodes in a pro-active way. According to embodiments, a fog monitoring controller may autonomically and/or autonomously discover and/or set up (e.g., configure, instantiate, allocate resources for, etc.) fog agents.

Autonomic Setup of Fog Monitoring Framework

[0103] FIG. 6 is an exemplary diagram illustrating autonomic instantiation of a fog resource monitoring framework according to embodiments.

[0104] According to embodiments, a fog monitoring framework may be set up (e.g., instantiated) in an autonomic way. According to embodiments, fog nodes may autonomously (e.g., autonomically) start fog agents (e.g., FMAs) at a bootstrapping, and the fog nodes may then start looking for any of other agents (e.g., FMAs) and the fog monitoring controller.

[0105] According to embodiments, autonomic setup (e.g., instantiation of fog agents, as shown in FIG. 6), may be performed using an autonomic protocol, such as GRASP. According to embodiments, autonomic setup (e.g., instantiation of fog agents, as shown in FIG. 6), may include any of the hereinbelow discussed operations.

[0106] According to embodiments, a first operation may include a fog monitoring controller sending (e.g., regular, periodic) multicasts, for example, including advertisement messages. According to embodiments, the advertisement messages may include information indicating any of an ID associated with the fog monitoring controller and a scope for the advertisement messages, for example, the scope of where the messages may (e.g., need/have to) be flooded. According to embodiments, the advertisement messages may be multicast using a suitable method, such as, for example, any of: enhancements to GRASP, IPv6 neighbor discovery, Universal Plug and Play, etc.

[0107] According to embodiments, in the case of GRASP, M_DISCOVERY messages may be used with, for example, the addition of (e.g., new) objectives and objective options (e.g., that are needed). With respect to an objective option, GRASP specifies that the objective option identifies objectives for the purposes of discovery, negotiation or synchronization. According to embodiments, (e.g., new) objective options may be defined for (e.g., the purposes of) discovering (e.g., potential and/or existing) fog agents with certain characteristics. According to embodiments, non-limiting examples of these objective options may including any of the following (however, the names and/or extensions are just examples, and such may have to be registered, for example, by the Internet Assigned Numbers Authority (IANA)): (1) FOGNODERADIO: may be used to specify a given type of radio technology, e.g., WiFi (version), D2D, LTE, 5G, Bluetooth (version), etc.; (2) FOGNODECONNECTIVITY: may be used to specify a given type of connectivity, e.g., layer-2, IPv4, IPv6; (3) FOGNODEVIRTUALIZATION: may be used to

specify a given type of virtualization supported by the node where the agent runs, e.g., hypervisor (type), container, micro-kernel, bare-metal, etc.; and (4) FOGNODEDOMAIN: may be used to specify the domain/owner of the node, e.g., to support operation of multiple domains/operators simultaneously on the same fog network.

[0108] According to embodiments, a discovery message (e.g., using GRASP) may be (e.g., the fog monitoring controller being identified by its IPv6 address: 2001:DB8:1111:2222:3333:4444:5555:6666):

[M_DISCOVERY, 13948745, h'20010db8111122223333444455556666',
["FOGDOMAIN", F_SYNCH_bits, 2, "operator1"]]

According to embodiments, GRASP may be used to allow for autonomic discovery of any of the fog agents (e.g., FMAs) and/or the controller. According to embodiments, extensions (e.g., as defined above), together with use of (e.g., properly scoped) multicast addresses (see below), may provide information associated with (e.g., precise defining of) nodes participating in the monitoring and gathering of principal characteristics of such nodes. GRASP has been conceived for use in networks to allow self-discovery and configuration of distributed nodes. According to embodiments, GRASP may be extended to (e.g., allow nodes and/or agents to) perform self-discovery and configuration in distributed fog environments, wherein some nodes, such as an orchestrator and a fog monitoring controller, may play a centralized role.

[0109] According to embodiments, a second operation may include, in a case of a fog node, such as fog nodes A and B in FIG. 6, such fog nodes may bootstrap and may start sending multicast discovery messages within a given scope. That is, the fog nodes may send multicast discovery messages, for example, within the intended area that is (e.g., defines, makes up, composes, includes, etc.) the fog. According to embodiments, a definition of a scope may depend on a scenario (e.g., context, environment). According to embodiments, possible scopes may be any of: (e.g., any, certain, all, etc.) resources of a given manufacturer, (e.g., any, certain, all, etc.) resources of a given type, (e.g., any, certain, all, etc.) resources of a given administrative domain, (e.g., any, certain, all, etc.) resources of a given user, (e.g., any, certain, all, etc.) resources within a topological network distance (e.g., a number of hops), (e.g., any, certain, all, etc.) resources within a geographical location, etc. According to embodiments, a scope may be (e.g., include) combinations of and/or with previous scopes.

[0110] According to embodiments, discovery messages may be multicast within the scope, for example, to reach (e.g., all) nodes that compose the specified fog resources. Such multicasting may be done, for example, using well defined IPv6 multicast addresses. According to embodiments, such multicast addresses, e.g., IPv6 multicast addresses, may be specified for each of the different scopes, and such signaling may be based on extensions to GRASP. According to embodiments, in a case of GRASP being used, then different IPv6 multicast addresses may be defined to reach each different scope, for example, using scopes equal or larger than Admin-Local according to RFC 7346.

[0111] According to embodiments, a third operation may include a fog monitoring controller responding to multicast fog discovery messages, for example, by replying with unicast information messages. According to embodiments, a fourth operation may include fog agents (e.g., FMAs) registering with a controller. According to embodiments, the registration message may be a unicast message, and may include information indicating fog node capabilities, such as any of: a type of node, a vendor, an energy source (e.g., battery-powered or not), a connectivity (e.g., number of network interfaces and/or information associated to them, such as radio technology type, layer-2 and layer-3 addresses, etc.), and a type of virtualization supported by the node running the fog agent, etc. According to embodiments, registration to multiple fog monitoring controller instances (e.g., instantiations) may be possible, for example, in a case where a fog node determines (e.g., wants) to belong to several fog domains (e.g., at the same time). According to embodiments, the orchestration of the same resource may be done by multiple orchestrators, for example, according to any suitable method. The defined mechanisms support such registration via the use of fog IDs and FOGNODEDOMAIN options.

[0112] According to embodiments, a fifth operation may include a fog node C, for example, that bootstraps after fog nodes A and B are already registered. According to embodiments, a discovery process (e.g., same as discussed above) may be followed by fog node C. Further, according to embodiments (e.g., in addition to such above discussed discovery process advertisement and registration procedures), existing neighboring fog agents (e.g., FMAs, fog agents A and B) may (e.g., also) respond to discovery messages sent by bootstrapping nodes (e.g., fog node C), for example, to provide required information. In such a case, the procedure may be faster, more efficient and reliable. According to embodiments, in addition to helping the fog monitoring controller in the fog

agent discovery process, fog agents may themselves learn about the existence and associated capabilities of other fog agents. In such a case, it may be possible to allow autonomous monitoring by the fog agents, for example, without the involvement of a central controller.

[0113] According to embodiments, a multi-operator and/or multi-player environment may be supported, for example, to have different operators at/in the fog. According to embodiments, each operator may deploy its own monitoring framework, and fog nodes may discover and register to different controllers.

Network-Service Specific Monitoring for Predictive “Make-Before-Break” Orchestration

[0114] FIG. 7 is a diagram illustrating network-service specific monitoring and orchestration according to embodiments.

[0115] According to embodiments, a fog monitoring framework may be used to perform network-service specific monitoring for predicting events and reacting to such at an orchestration level, for example, before the events may (e.g., actually) impact a running service. According to embodiments, network-service specific monitoring may include any of the following operations.

[0116] According to embodiments, a first operation may include orchestration logic (e.g., an NFVO) providing information to a fog monitoring controller. The provided information may include information available at the orchestration logic (e.g., obtained during the discovery and association process), such as any of: available virtualized compute resources, available virtualized storage resources, available virtualized networking resources, type of virtualization (e.g., full virtualization, para virtualization, hybrid virtualization), available hypervisor (e.g., bare metal or hosted hypervisor, version of the hypervisor), supported virtual machine images or container format, power profile (e.g., power source, battery or mains powered, battery capacity, charge status, etc.), volatility profile (e.g., expected availability), type of VIM and/or version, protocol APIs supported by the VIM, URI of the VIM, GPSI, and virtual data network name (DNN) or 5G LAN Group ID.

[0117] According to embodiments, orchestration related requirements may also be provided (e.g., in addition to the information available at the orchestration logic). For example, according to embodiments, orchestration related requirements may be used by the controller to autonomously (e.g., autonomically) decide which aspects should be

monitored (e.g., on each of the fog nodes) and which type of events may (e.g., would, should, need to, etc.) trigger an interaction with the orchestration logic. In a case where no service is yet running, the orchestration related requirements may not be fine grained (e.g., may not be service and/or function-specific). According to embodiments, requirements provided by the orchestration logic may include any of a target service availability level and a target connectivity availability. The target service availability level may indicate (e.g., a goal for an amount of) a time a resource is required to be available. According to embodiments, this information may be used, as discussed below, to configure triggers, such as those related to any of battery-level or availability of resources. The target connectivity availability may indicate (e.g., a goal for) a connectivity from a resource. For example, the connectivity availability may be indicated in terms of any of expected reachable time or possible sporadic connectivity disruptions (e.g., if mobile nodes are too mobile, frequent disconnections may happen).

[0118] According to embodiments, a fog monitoring controller may obtain additional information, for example, that was not provided to the orchestration logic during any of discovery and association process(es). That is, according to embodiments, a fog monitoring controller may contact fog nodes, for example, using/via fog agents (e.g., FMAs) running on each of the fog nodes to obtain additional information. According to embodiments, the additional information may include any of: a type of connectivity for egress and/or ingress interfaces, which may be: layer-2 type (e.g., Ethernet, WiFi, FFTH, Docsis, including speed and specification version), layer-3 type (e.g., IPv4 public, IPv4 private behind NAT, IPv4 private isolated, IPv6, dual stack, etc.), anonymity support via address randomization, tunneling support (e.g., GRE, VxLAN, IPsec VPN, etc.), etc.; mobility support (e.g., fixed node or mobile node); and availability records (e.g., indicating last known non-stop periods of activity, for example, between reboots) and/or availability (e.g., duration of periods when available for hosting functions).

[0119] According to embodiments, a second operation may include a network service, for example, in the form of a service function chain F1-F2, being requested to the orchestration logic. According to embodiments, there may be (e.g., specific) requirements for each of the functions and for each connectivity (e.g., connection) between the functions and the end-points of the service. For example, such requirements may be (e.g., typically) specified in a network service descriptor (NSD). According to embodiments, the orchestration logic may request (e.g., the fog monitoring controller to provide) an update

of the status of the resources. The request may include filtering parameters, for example, to provide minimum requirements that the resources have to meet. According to embodiments, the fog monitoring controller may provide the orchestration logic with an updated view of the resources, for example, by filtering those resources that do not meet the requirements (e.g., if they were provided).

[0120] According to embodiments, a third operation may include the orchestration logic deciding where to place (e.g., where to dispose, instantiate, etc.) F1 and F2, and how to interconnect them, for example, by determining any of an overlay network and type of interconnection. As shown in FIG. 7, F1 is hosted at fog node A, and F2 is hosted at fog node B. According to embodiments, the orchestration logic may instantiate any of the functions and the connectivity between the instantiated functions.

[0121] According to embodiments, a fourth operation may include the orchestration logic informing a fog monitoring controller about an instantiated network service (e.g., F1@A-F2@B, that is, F1 is at fog node A and F2 is at fog node B). According to embodiments, the informing about an instantiated network service may include any of: where functions F1 and F2 have been instantiated (e.g., location, instantiation, and/or placement information), requirements of the functions (e.g., in terms of any of: computing, connectivity, availability, specific hardware needs, coverage, etc.), how F1 and F2 are interconnected (e.g., type of overlay network, network specific parameters, such as IP addresses, VLAN IDs, etc.), and requirements of the F1-F2 interconnection (e.g., delay, jitter, bandwidth, disruption tolerance, etc.).

[0122] According to embodiments, in a case where information is provided by the orchestration logic, a fifth operation may include the fog monitoring controller deciding (e.g., determining) aspects that may (e.g., have to, need to, etc.) be monitored, and/or how to monitor such aspects, on fog nodes and links. According to embodiments, such fog node may include any of the (e.g., different, currently participating) nodes and links (e.g., including links set up for alert notification triggers), as well as on neighboring nodes that may participate in providing a service. According to embodiments, these aspects may include any of: node-specific alert thresholds (e.g., battery level), connectivity measurements (e.g., obtained by setting probes on different nodes and configuring measurements, such as frequency, type of measurement, etc., to be performed), measurements involving other fog nodes, access level monitoring events (e.g., reporting of events related to cellular network operation, such as WTRU mobility and/or WTRU

availability), and frequency of monitoring (e.g., locally at each node and/or in terms of reporting to the controller).

[0123] According to embodiments, in the case of measurements involving other fog nodes, some measurements may involve (e.g., participation of) other fog nodes, for example, through their fog agents (e.g., FMAs). According to embodiments, these involved (e.g., participating) fog nodes may be part of a network service (e.g., to measure the delay of an active link of the service) or not (e.g., to evaluate other potential candidates for hosting a function in a case where a migration is needed). According to embodiments, a fog monitoring controller may subscribe to relevant events from the NEF, for example, by providing an external identifier associated to any of a fog resource or a group identifier, such as a 5G LAN identifier or Virtual Data Network associated to a group such as a 5G LAN.

[0124] According to embodiments, a fog monitoring controller may provide information associated with (e.g., specific to) a network service, such as network service identifiers, and may request monitoring of resources assigned to a (e.g., particular) network slice and/or group of network slices (e.g. any of computing, networking, and storage resources) that may be associated to the network service identifier provided by the fog monitoring controller. In such a case, the controller may (e.g., request to) be informed when no network slices associated to the provided network service identifier are available (e.g., any longer) and/or when a (e.g., particular) slice requested by the fog resource is not compatible with other network slices already assigned to the fog resource. According to embodiments, the NEF may confirm the monitoring request.

[0125] According to embodiments, a fog monitoring controller may apply a logic, for example, similar that used by an orchestrator when computing function placement and when making resource orchestration decisions. Furthermore, such logic may be applied with a goal, for example, different than the goal of logic applied by/for an orchestrator. That is, orchestration decisions may be (e.g., typically) based on the current status of the resources, which are assumed to be reasonably stable (e.g., they may fail, but may not (e.g., be expected to) vary much). In contrast, according to embodiments, actions performed by a fog monitoring controller may predict situations associated with (e.g., requiring, triggering, needing, etc.) an orchestration decision. For example, in the case, as shown in FIG. 7 having three fog nodes, a network service composed of F1-F2 may be instantiated, where F1 runs on fog node A and F2 runs on fog node B. In such a case,

the connectivity between F1 and F2 (e.g., a logical link) may be configured using VxLAN. According to embodiments, the service may have any of the following requirements: F1-F2 max delay of 10 ms, F1-F2 bandwidth of 1Mbps, service required availability of 3600 seconds, and service criticality of/being high.

[0126] According to embodiments, with, for example, these requirements and, the information regarding both where F1 and F2 are placed and how the logical link is configured, the fog monitoring controller may decide (e.g., determine) to configure probes (e.g., with a given reporting frequency) on the fog agents (e.g., FMAs) at fog nodes A and B to monitor the delay and/or evaluate the bandwidth. According to embodiments, the bandwidth may be evaluated by passively looking at the exchanged traffic and by analyzing the information from the radio interfaces used by fog nodes A and B. Alerts for battery lifetime may also configured on nodes A and B.

[0127] According to embodiments, an alert may (e.g., also) be used as (e.g., to setup a) check (e.g., determine, monitor, etc.) when radio quality of the link between fog nodes A and B goes below a threshold (e.g., which may indicate any of that the nodes may be moving away, and the link may fail). According to embodiments, for example, in a case where a service is critical, a fog monitoring controller may (e.g., also) configure the fog agent (e.g., FMA) on node C to evaluate any of the delay and bandwidth with fog nodes A and B, and corresponding battery lifetime. This monitoring may be done by any of: periodically reporting by fog node C to the controller, autonomously reporting by fog node C; and (e.g., in the case of autonomously reporting, only) reporting if queried by the controller and/or by another fog agent. According to embodiments, such monitoring may be used (e.g., is needed) because the monitoring and prediction is may be performed by the logically centralized fog monitoring controller, and also by the fog agents.

[0128] There may be a case where fog node A is moving away from its current region. According to embodiments, in such a case, it may be assumed that the orchestration logic requested to be notified regarding such moving away is an event. According to embodiments, a sixth operation may include the fog monitoring controller receiving an alert in the case of such mobility. For example, because the fog monitoring controller configured a fog agent (e.g., FMA) running at fog node A to send an alert in the case of such mobility. The event of mobility may be detected by the fog node, for example, by using different mechanisms, according to a type of node (e.g., from internal sensors such as accelerometers, to hints based on perceived signal level, etc.).

[0129] According to embodiments, in a case where an access dependent event (e.g., a user plane function (UPF) reallocation) may (e.g., is about to) take place, the NEF may communicate the event to a fog monitoring controller. According to embodiments, any of an accuracy and an anticipation linked to a particular event may depend on how the monitoring controller uses the monitoring events available at the NEF. For example, monitoring events associated with geographical location change may signal imminent departure of a fog node away from the area where it is allowed to operate machinery, such as a robot.

[0130] According to embodiments, a seventh operation may include the fog monitoring controller notifying (e.g., to the orchestration logic) that fog node A is becoming unavailable. According to embodiments, an eight operation may include the orchestration logic requesting an update to the fog monitoring controller, for example, to have an updated view of resources. According to embodiments, based on (e.g., by considering) received information, the orchestration logic may decide to move function F1 to a different fog node (e.g., fog node C). Further, according to embodiments, since fog node C was identified as a potential candidate to host a function of the service and was already being monitored, the fog monitoring controller may determine to suggest fog node C as a candidate hosting node and may provide such a suggestion to the orchestration logic.

[0131] Although features and elements are described 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. In addition, the methods described 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 non-transitory computer-readable storage media include, but are not limited to, a read only memory (ROM), 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 UE, WTRU, terminal, base station, RNC, or any host computer.

[0132] Moreover, in the embodiments described above, processing platforms, computing systems, controllers, and other devices including the constraint server and the rendezvous point/server 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".

[0133] 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 exemplary embodiments are not limited to the above-mentioned platforms or CPUs and that other platforms and CPUs may support the provided methods.

[0134] 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 is understood that the representative embodiments are not limited to the above-mentioned memories and that other platforms and memories may support the described methods.

[0135] 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.

[0136] 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 vs. efficiency tradeoffs. There may be various vehicles

by which processes and/or systems and/or other technologies described herein may be affected (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.

[0137] 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. Suitable processors include, by way of example, a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Application Specific Standard Products (ASSPs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), and/or a state machine.

[0138] 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.

[0139] 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, 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 infra; (ii) any of a number of embodiments of a WTRU, such as described infra; (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 infra; (iii) a wireless-capable and/or wired-capable device configured with less than all structures and functionality of a WTRU, such as described infra; or (iv) the like. Details of an example WTRU, which may be representative of any WTRU recited herein.

[0140] In certain representative embodiments, 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.).

[0141] 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 intermediate 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.

[0142] 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.

[0143] 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" or "group" 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.

[0144] 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.

[0145] 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.

[0146] 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.

[0147] A processor in association with software may be used to implement a radio frequency transceiver for use in a wireless transmit receive unit (WTRU), user equipment (UE), terminal, base station, Mobility Management Entity (MME) or Evolved Packet Core (EPC), or any host computer. The WTRU may be used in conjunction with modules, implemented in hardware and/or software including a Software Defined Radio (SDR), and other components such as a camera, a video camera module, a videophone, a speakerphone, a vibration device, a speaker, a microphone, a television transceiver, a hands free headset, a keyboard, a Bluetooth® module, a frequency modulated (FM) radio unit, a Near Field Communication (NFC) Module, a liquid crystal display (LCD) display unit, an organic light-emitting diode (OLED) display unit, a digital music player, a media player, a video game player module, an Internet browser, and/or any Wireless Local Area Network (WLAN) or Ultra Wide Band (UWB) module.

[0148] Although the invention has been described in terms of communication systems, it is contemplated that the systems may be implemented in software on microprocessors/general purpose computers (not shown). In certain embodiments, one or more of the functions of the various components may be implemented in software that controls a general-purpose computer.

[0149] In addition, although the invention is illustrated and described herein with reference to specific embodiments, the invention is not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

CLAIMS

What is claimed is:

1. A method for monitoring including autonomic set-up and registration of any of a Fog Monitoring Controller (FMC) and Fog Agents (FAs), the method comprising:

receiving, by a FA, from the FMC, multicast advertisement messages advertising the FMC via an interface connecting the FMC and the FA, the multicast advertisement messages including information indicating any of an identity (ID) of the FMC and a FMC scope associated with the FMC;

transmitting, by the FA, to the FMC, multicast discovery messages, the multicast discovery messages, including any of a fog node ID and a respective fog node scope associated with each fog node, the multicast discovery messages including information notifying the FMC about any number of resources associated with a fog node hosting the FA;

receiving, by the FA, from the FMC in response to the multicast discovery messages, unicast advertisements including information indicating any of: an ID associated with the fog monitoring, the ID of the FMC, and the scope associated with the FMC; and

transmitting, by the FA, to the FMC, unicast registration messages including information indicating that the FA is registered for fog monitoring.

2. The method of claim 1, wherein the unicast registration message includes information associated with any of an ID of a fog node, an ID associated with the fog monitoring, a scope of the fog node, and capabilities of the fog node.

3. The method of claim 2, wherein the information associated with the capabilities of the fog node may be information indicating any of: a type of node, vendor, an energy source, a connectivity, or a type of virtualization supported by the fog node.

4. The method of claim 2, wherein a scope associated with any of the FMC or FAs includes any of: resources of a manufacturer, resources of a type, resources of an administrative domain, resources of a given user, resources within a topological network distance, and resources within a geographical location.

5. The method of claim 4, wherein different multicast IP address are associated with different scopes when the WTRUs are transmitting multicast discovery messages.
6. The method of claim 1, wherein any of the messages transmitted between any of the FMC and the FAs may be any of: a generic autonomic signaling protocol (GRASP) message, an extended IPv6 Neighbour Discovery message, and an extended Universal Plug and Play message.
7. The method of claim 6, wherein an objective type of the GRASP message is any of: FOGNODERADIO, FOGNODECONNECTIVITY, FOGNODEVIRTUALIZATION, and FOGNODEDOMAIN, for the purpose of discovering potential FAs with certain characteristics including any of: type of radio technology, type of connectivity, type of supported virtualization, and administrative domain associated to the node.
8. A WTRU that is a Fog Node executing any number of Fog Agents (FAs) for fog monitoring including autonomic set-up and registration of any of a Fog Monitoring Controller (FMC) and any number of FAs, the WTRU configured to:
- receive, from a FMC, multicast advertisement messages advertising the FMC via an interface connecting the FMC and a FA, the multicast advertisement messages including information indicating any of an identity (ID) of the FMC and a FMC scope associated with the FMC;
 - transmit, to the FMC, multicast discovery messages, the multicast discovery messages, including any of a fog node ID and a respective fog node scope associated with each fog node, the multicast discovery messages including information notifying the FMC about any number of resources associated with the fog node hosting the FA;
 - receive, from the FMC in response to the multicast discovery messages, unicast advertisements including information indicating any of: an ID associated with the fog monitoring, the ID of the FMC, and the scope associated with the FMC; and
 - transmit, to the FMC, unicast registration messages including information indicating that the FA is registered for fog monitoring.
9. The WTRU of claim 8, wherein the unicast registration message includes information associated with any of an ID of the fog node, an ID associated with the fog monitoring, a scope of the fog node, and capabilities of the fog node.

10. The WTRU of claim 9, wherein the information associated with the capabilities of the fog node may be information indicating any of: a type of node, vendor, an energy source, a connectivity, or a type of virtualization supported by the fog node.
11. The method of claim 9, wherein a scope associated with any of the FMC or FAs includes any of: resources of a manufacturer, resources of a type, resources of an administrative domain, resources of a given user, resources within a topological network distance, and resources within a geographical location.
12. The method of claim 11, wherein different multicast IP address are associated with different scopes when the WTRUs are transmitting multicast discovery messages.
13. The method of claim 8, wherein any of the messages transmitted between any of the FMC and the FAs may be any of: a generic autonomic signaling protocol (GRASP) message, an extended IPv6 Neighbour Discovery message, and an extended Universal Plug and Play message.
14. The method of claim 13, wherein an objective type of the GRASP message is any of: FOGNODERADIO, FOGNODECONNECTIVITY, FOGNODEVIRTUALIZATION, and FOGNODEDOMAIN, for the purpose of discovering potential FAs with certain characteristics including any of: type of radio technology, type of connectivity, type of supported virtualization, and administrative domain associated to the node.
15. A method for providing fog monitoring for predicting monitoring events triggering an orchestration action by a Fog Monitoring Controller (FMC), the method comprising:
- receiving, by the FMC, from a management and orchestration (MANO), information indicating any of service-specific information and orchestration related requirements, via an interface connecting the FMC to the MANO;
 - receiving, by the FMC, from any number of Fog Agents (FAs), information associated with any of the FAs and fog monitoring resources not known by the MANO;
 - determining, by the FMC, upon a network service instantiation by the MANO, any of aspects, parameters, and conditions for fog monitoring and any number of FAs for performing the fog monitoring, and setting up alert notification triggers;

transmitting, by the FMC, to any number of FAs, a monitoring request message associated with any number of monitoring events;

receiving, by the FMC, from any number of FAs detecting a monitoring event, a notification message including information associated with the detected monitoring event; and

transmitting, by the FMC, to the MANO, a message including information associated with the detected monitoring event.

16. The method of claim 15, wherein the information received by the FMC from the MANO comprises any of: Available Virtualized Compute Resources, Available Virtualized Storage Resources, Available Virtualized Networking Resources, Type of virtualization, Available hypervisor, Version of the hypervisor, Supported virtual machine images or container format, Power profile, Volatility profile, Type of VIM and version, Protocol APIs supported by the VIM, URI of the VIM, GPSI, and Virtual DNN or 5G LAN Group ID.

17. The method of claim 15, wherein the orchestration related service specific requirements comprise any of: Target service availability level, and Target connectivity availability.

18. The method of claim 15, wherein the information received from any number of FAs comprises any of: type of connectivity, layer-2 type, layer-3 type, anonymity support, tunneling support, mobility support, available records of activity, and resource availability.

19. The method of claim 15 wherein, any of the aspects, the parameters, and the conditions determined by the FMC comprise any of: node-specific alert thresholds, connectivity measurements, measurements involving or relying on other FAs, and access level monitoring events.

20. The method of claim 15, wherein the FMC and the MANO are co-located at a same node.

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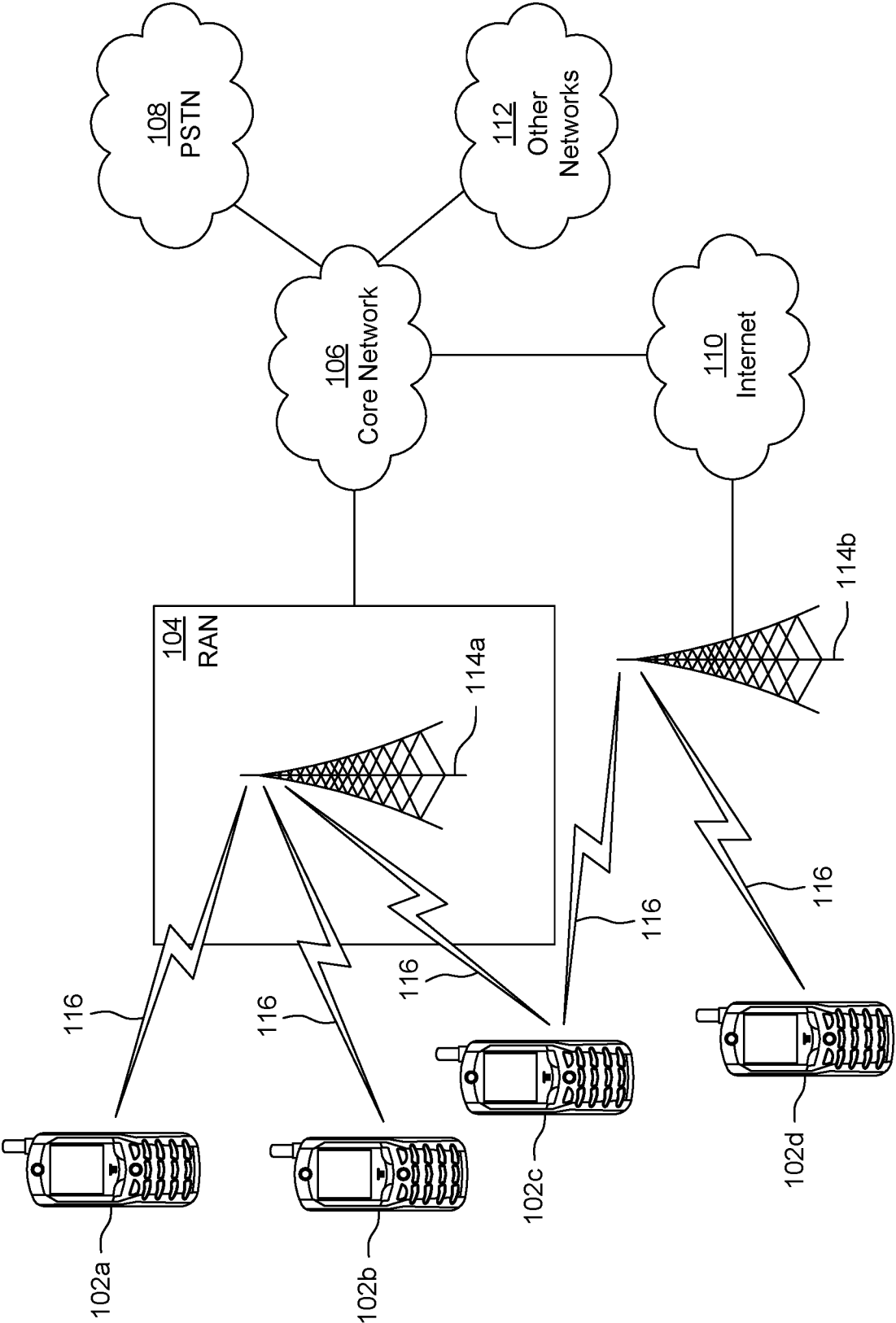


FIG. 1A

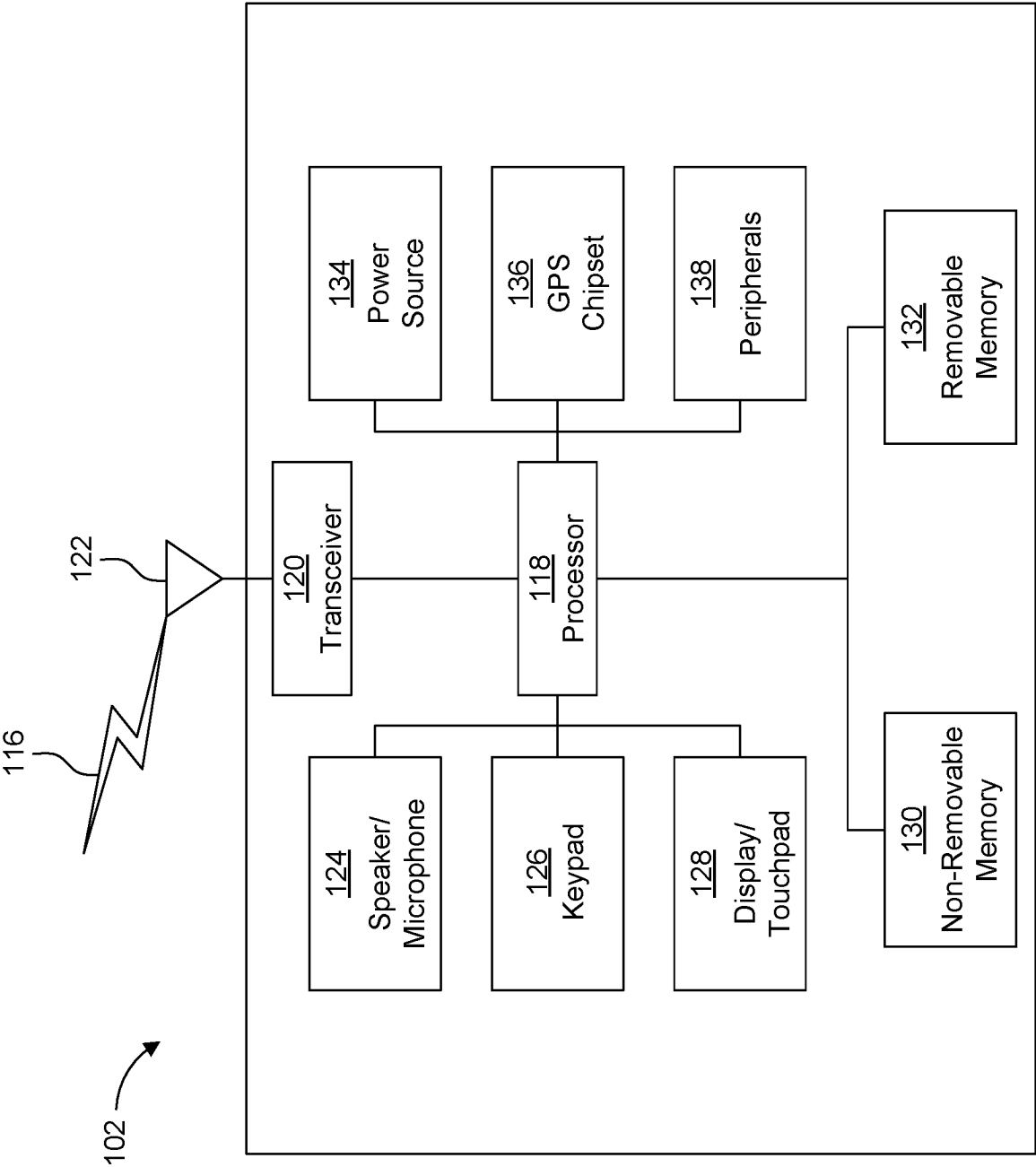


FIG. 1B

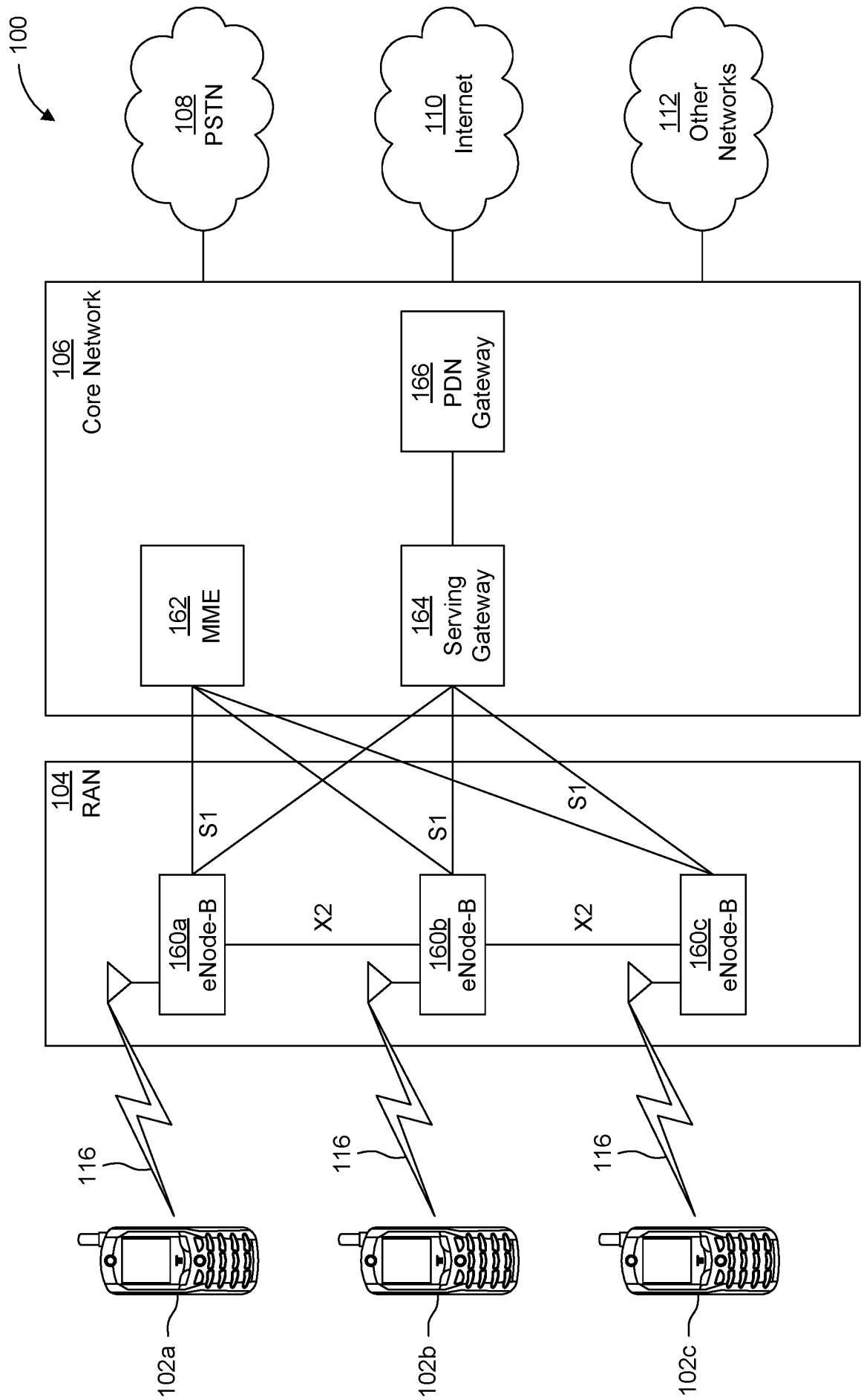


FIG. 1C

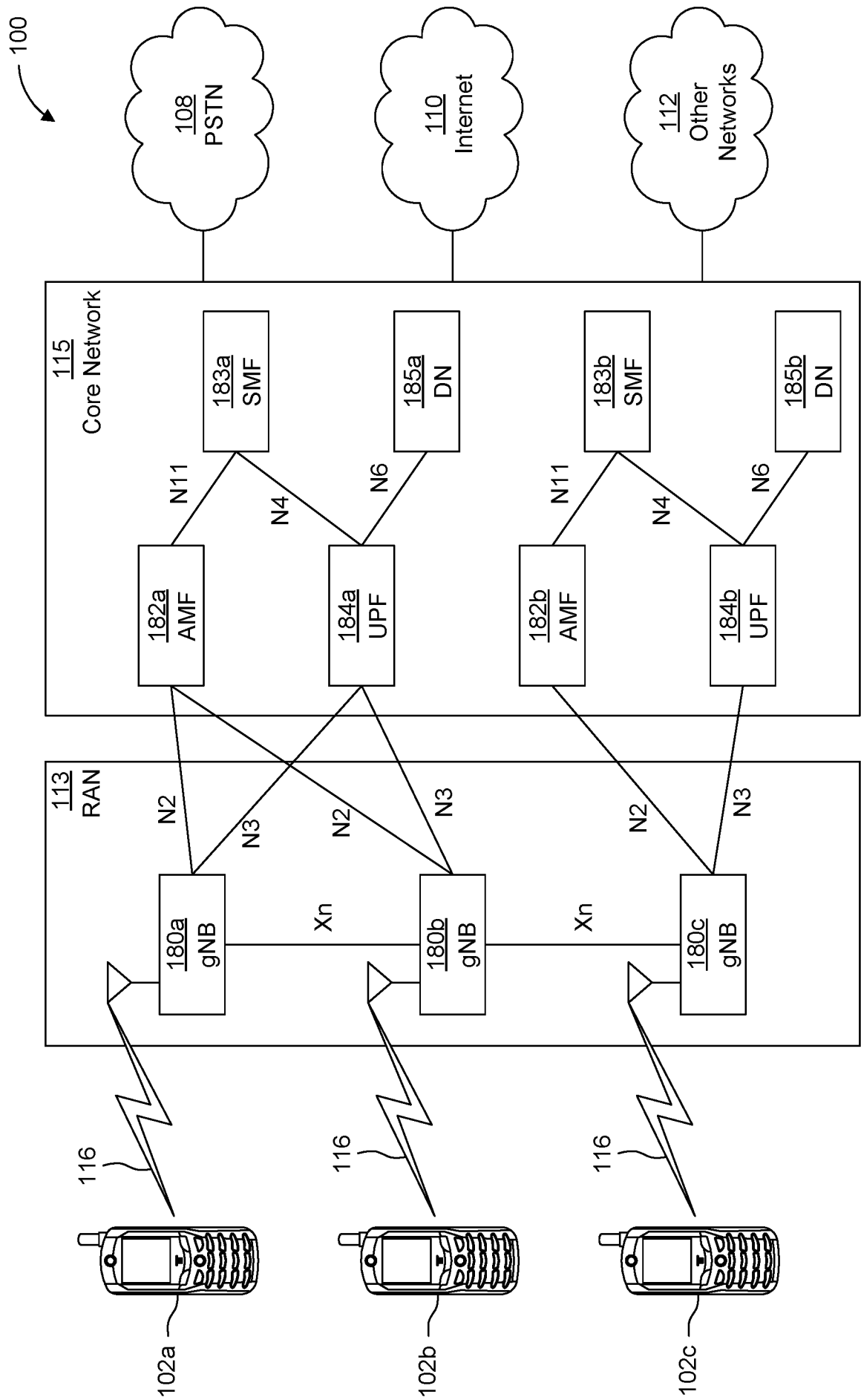


FIG. 1D

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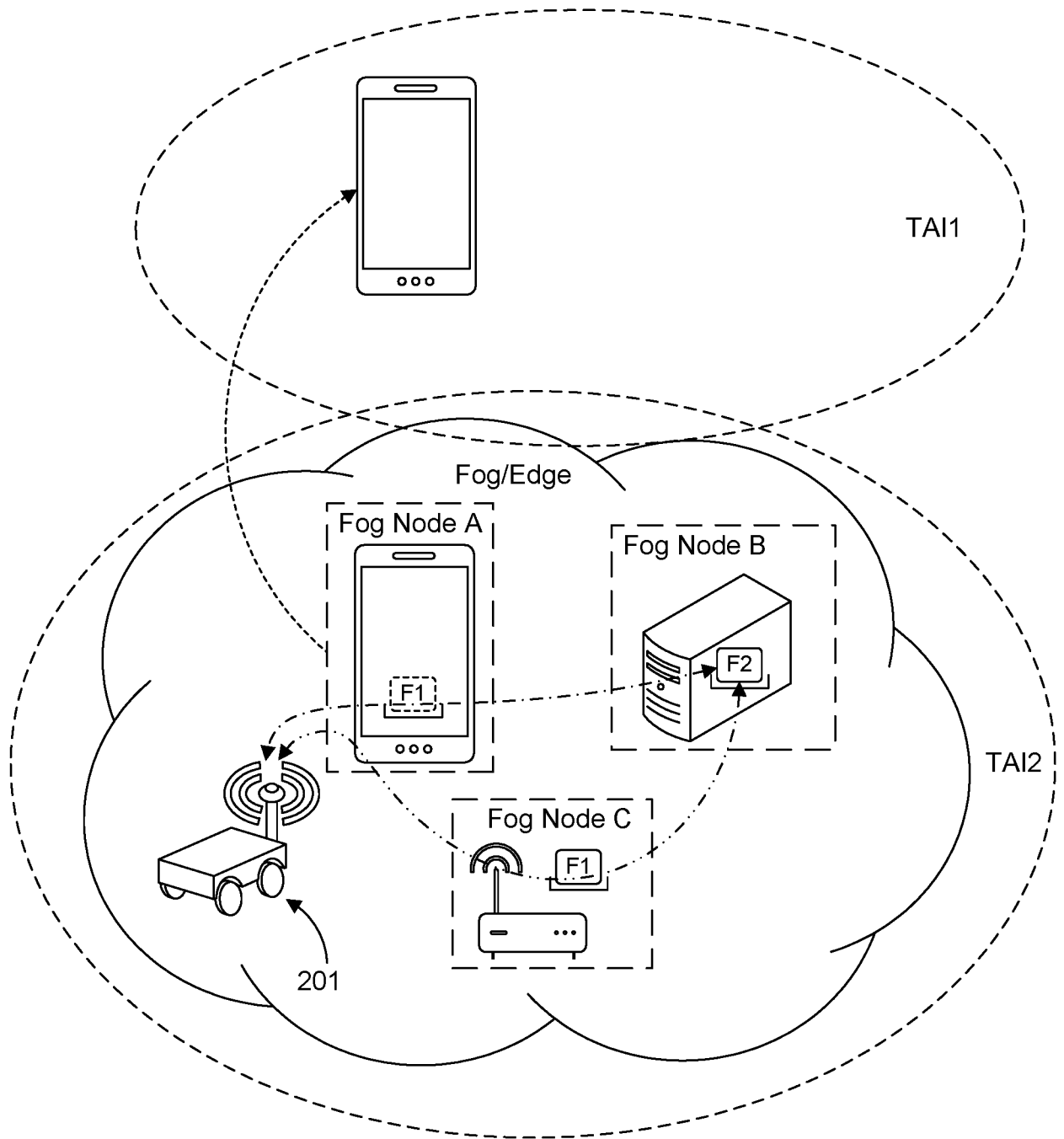


FIG. 2

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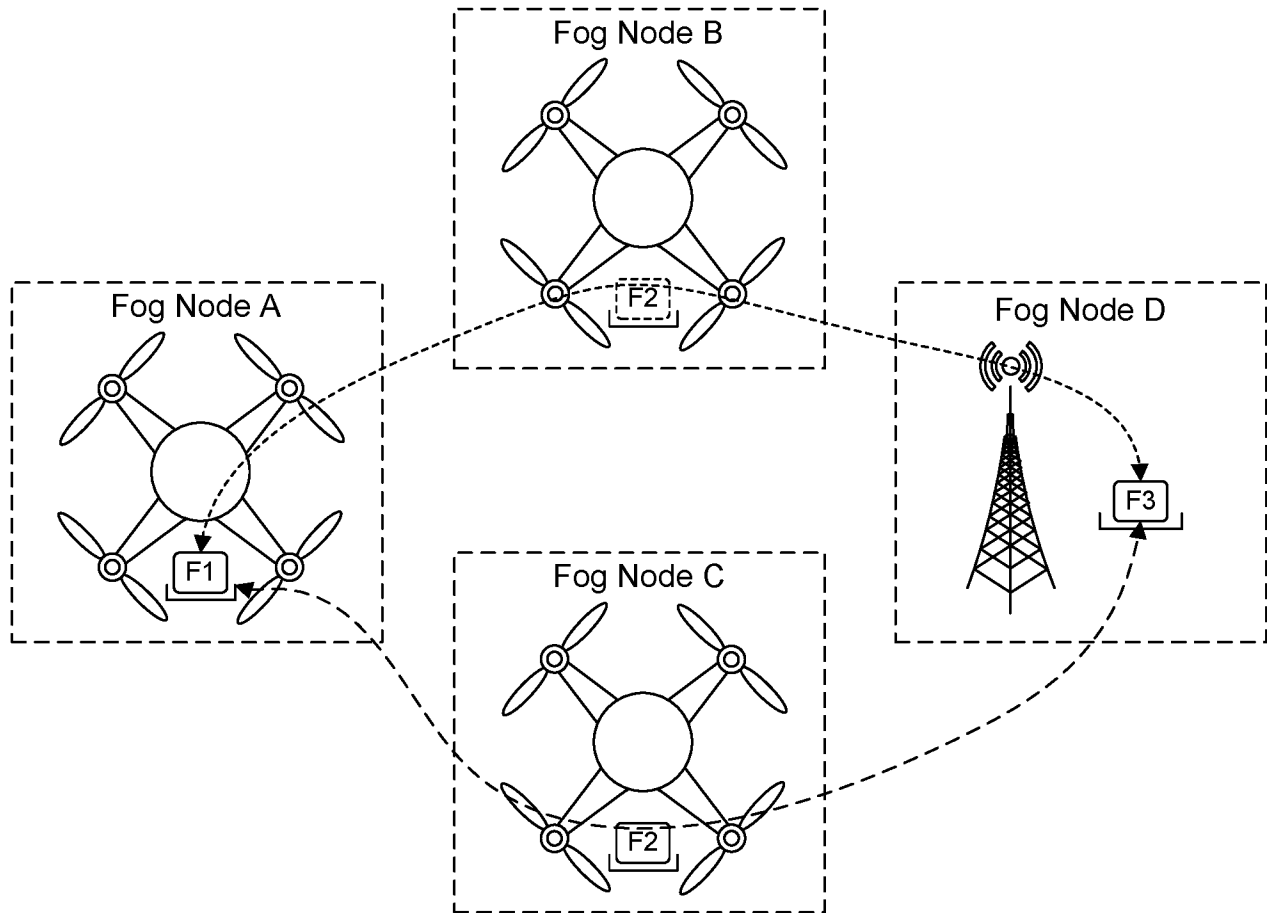


FIG. 3

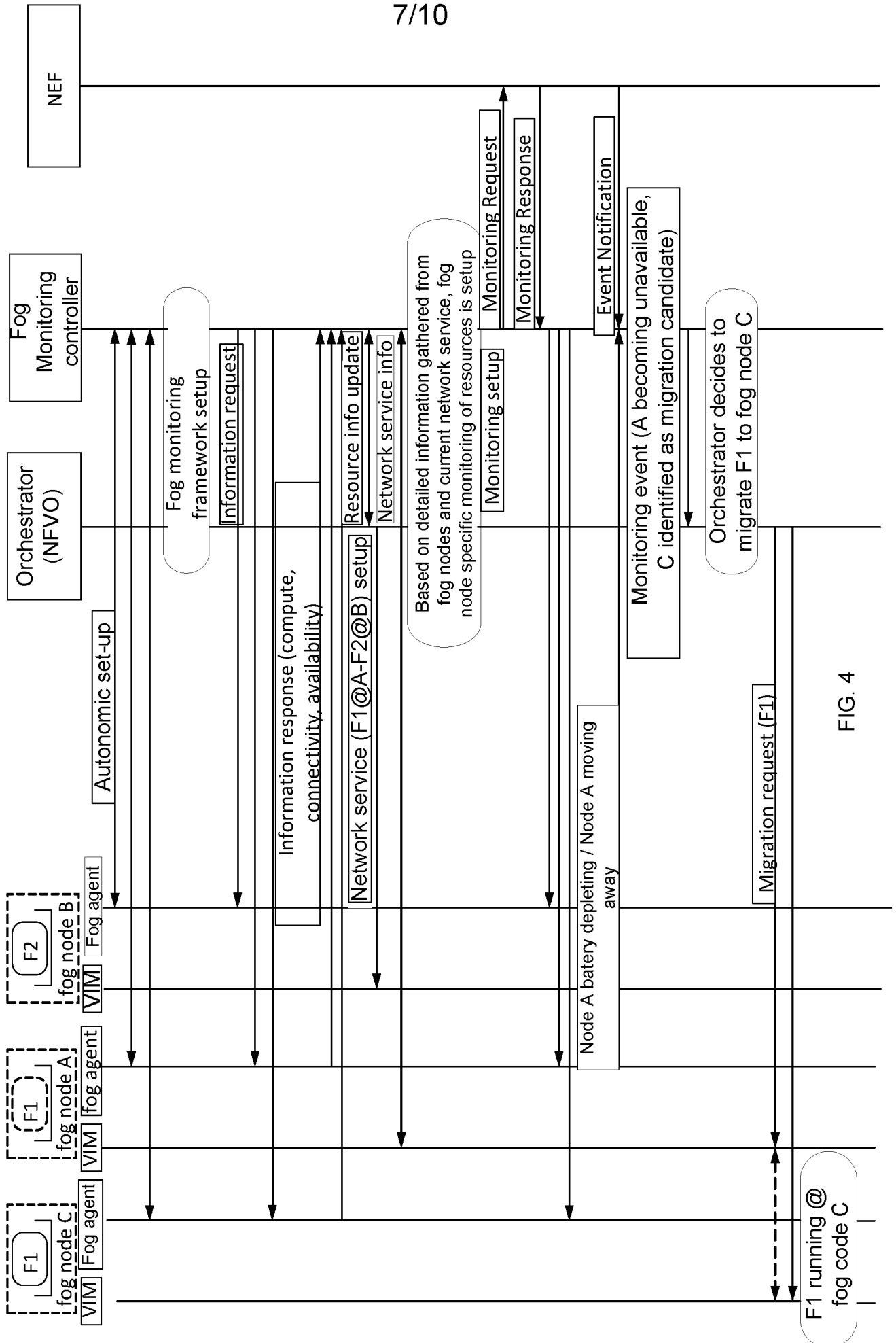


FIG. 4

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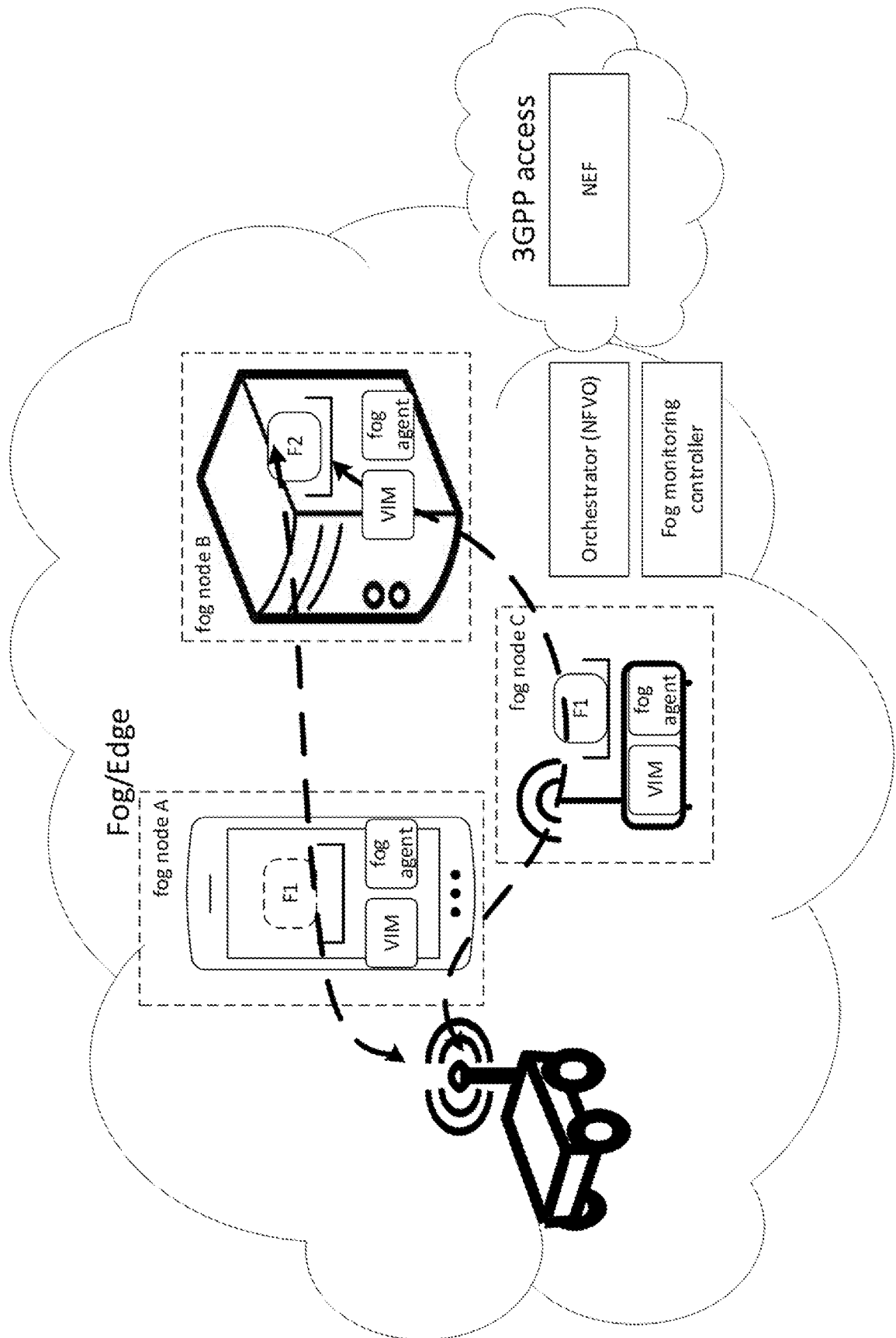


FIG. 5

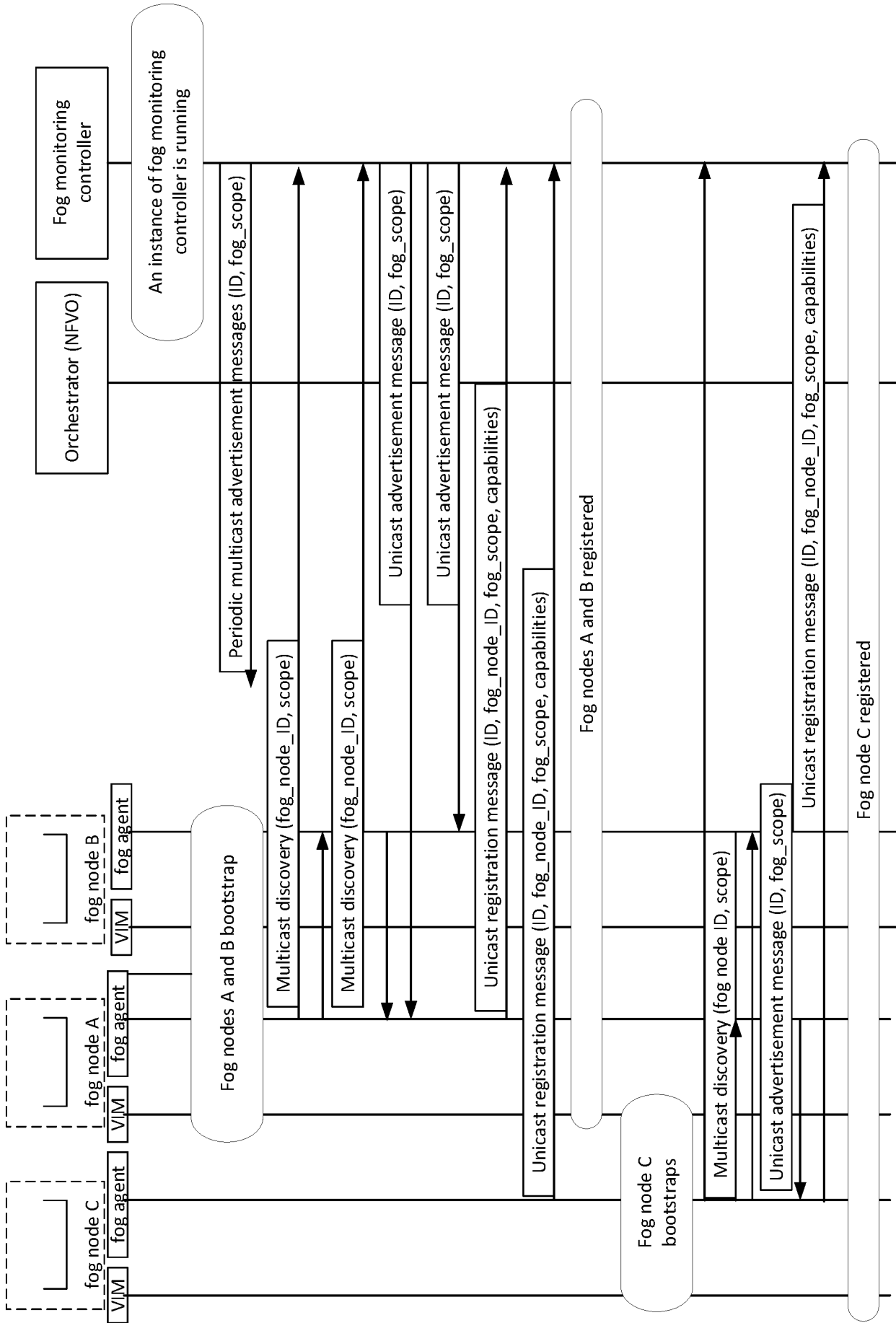


FIG. 6

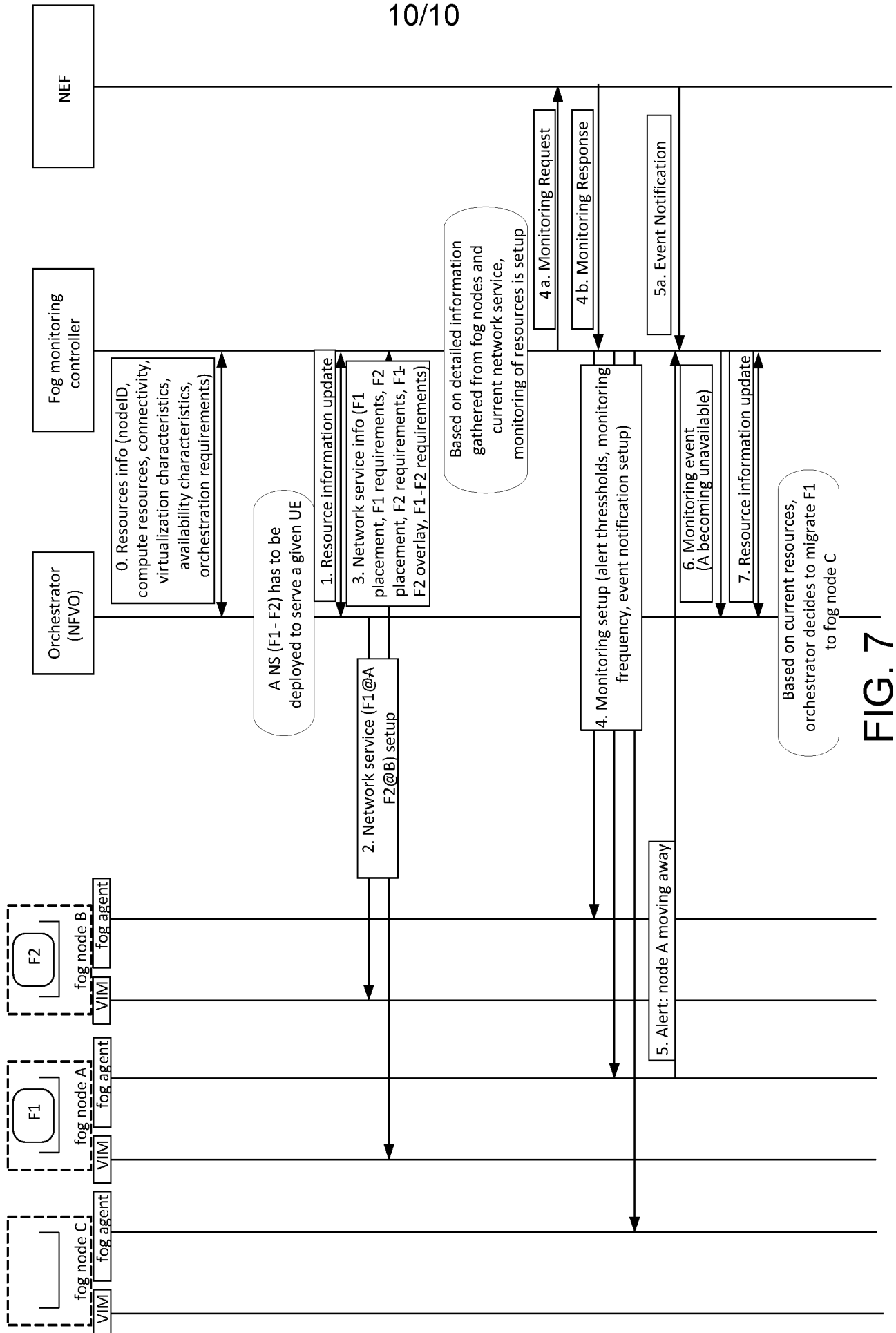


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/021468

A. CLASSIFICATION OF SUBJECT MATTER

INV. G06F11/30 H04L12/26 G06F9/50 H04L29/08 H04W4/70
H04L12/24

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)

G06F H04L H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE BRITO MATHIAS SANTOS ET AL: "A service orchestration architecture for Fog-enabled infrastructures", 2017 SECOND INTERNATIONAL CONFERENCE ON FOG AND MOBILE EDGE COMPUTING (FMEC), IEEE, 8 May 2017 (2017-05-08), pages 127-132, XP033105893, DOI: 10.1109/FMEC.2017.7946419 figures 2,3 section III section III.A section III.B section IV.B ----- -/-	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

3 June 2020

Date of mailing of the international search report

05/08/2020

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

Authorized officer

Cuevas Casado, A

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/021468

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	BORMANN UNIVERSITAET BREMEN TZI B CARPENTER C ET AL: "A Generic Autonomic Signaling Protocol (GRASP); draft-ietf-anima-grasp-15.txt", A GENERIC AUTONOMIC SIGNALING PROTOCOL (GRASP); DRAFT-IETF-ANIMA-GRASP-15.TXT; INTERNET-DRAFT: NETWORK WORKING GROUP, INTERNET ENGINEERING TASK FORCE, IETF; STANDARDWORKINGDRAFT, INTERNET SOCIETY (ISOC) 4, RUE DES FALAISES CH- 1205 GENEVA, SWITZERLAN, no. 15, 13 July 2017 (2017-07-13), pages 1-81, XP015120940, cited in the application abstract section 2.4 section 2.5.4.3 section 2.8.4 section 2.8.5 section 2.8.11 section 2.5.5 -----	1-14
A	GALIS UNIVERSITY COLLEGE LONDON K MAKHIJANI D YU B LIU HUAWEI TECHNOLOGIES A: "Autonomic Slice Networking; draft-galis-anima-autonomic-slice-networking-05.txt", AUTONOMIC SLICE NETWORKING; DRAFT-GALIS-ANIMA-AUTONOMIC-SLICE-NETWORKING-05.TXT; INTERNET-DRAFT: NO WORKING GROUP, INTERNET ENGINEERING TASK FORCE, IETF; STANDARDWORKINGDRAFT, INTERNET SOCIETY (ISOC) 4, RUE DES FALAISES CH- 1205 GENEVA, SWITZERLAND, no. 5, 27 September 2018 (2018-09-27), pages 1-24, XP015128724, section 5 section 11.5 ----- -/--	1-14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/021468

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	CJ BERNARDOS UC3M A MOURAD INTERDIGITAL: "Autonomic setup of fog monitoring agents; draft-bernardos-anima-fog-monitoring-00.tx t", AUTONOMIC SETUP OF FOG MONITORING AGENTS; DRAFT-BERNARDOS-ANIMA-FOG-MONITORING-00.TX T; INTERNET-DRAFT: ANIMA WG, INTERNET ENGINEERING TASK FORCE, IETF; STANDARDWORKINGDRAFT, INTERNET SOCIETY (ISOC) 4, , 11 March 2019 (2019-03-11), pages 1-11, XP015131700, Retrieved from the Internet: URL:https://tools.ietf.org/html/draft-bernardos-anima-fog-monitoring-00 [retrieved on 2019-03-11] the whole document -----	1-14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/021468

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-14

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-14

setting up an ad-hoc network

2. claims: 15-20

consolidating and proxying notifications
