

METHOD AND APPARATUS FOR ENABLING VERTICAL FEDERATED LEARNING BASED ON NETWORK INTERACTION WITH AN APPLICATION FUNCTION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 63/554,037 filed in the U.S. Patent and Trademark Office on February 15, 2024, the entire content of which being incorporated herein by reference as if fully set forth below in its entirety and for all applicable purposes.

BACKGROUND

[0002] A network data analytics function may provide information such as one or more statistics and/or one or more predictions based on a request from an entity. Examples of the information include base station (gNB) status information, gNB resource usage information, wireless transmit/receive unit (WTRU) communication information, and/or mobility performance in an area of interest etc. A target of such analytics may include a single WTRU, a group of WTRUs, and/or a WTRU that may be in an area of interest. The network data analytics function may be configured to characterize a load in one or more network functions and/or one or more network slices, the one or more predictions and/or the one or more statistics associated with WTRU mobility, one or more expected WTRU behaviors, and an observed service experience at multiple levels, such as on a per network slice, for a particular application, and/or for a particular application over a particular access type (e.g., a radio access technology (RAT) access type and/or one or more channel frequencies etc.).

SUMMARY

[0003] A vertical federated learning (VFL) technique uses a collaborative machine learning (ML) model among multiple independent training entities where each entity uses a corresponding dataset, which may have different features. In an example, for a given sample, some features may only be available in some of the training entities. The VFL process is performed between an application function (AF) and a 5G core (5GC) network (i.e. a mobile network) and may involve training of a local ML model and one or more corresponding training results may be used to update a global ML model.

[0004] The AF may provide the local ML model to the 5GC. The 5GC may utilize one or more data features acquired in the mobile network to train the local ML model. The training results of the local ML training in the 5GC may be shared with the AF. Based on the one or more training results, an updated local ML model may be provided to the 5GC for further ML model training. The AF may use the training results to update a global ML model.

[0005] Coordination between the 5GC and the AF may be required to perform the VFL process and generate the global ML model. In an example, the AF may need to determine whether the analytics services with the ML model are available for VFL and ensure that federated learning will provide an expected performance. The AF may determine an available local ML model and monitor one or more performance metrics of the VFL. The AF may update the VFL process if the expected performance is not achieved.

[0006] In one or more embodiments, a method performed by a network function (NF) is provided. The method comprises receiving, from an AF, a service request for information associated with one or more machine learning (ML) models for vertical federated learning (VFL). The method includes selecting, based on the service request, one or more federated learning network functions (FL_NFs) of a plurality of FL_NFs that support the one or more ML models for VFL. The method includes transmitting, to the AF, a service response indicative of the selected one or more FL_NFs.

[0007] In an embodiment, the method comprises selecting, based on the service request, one or more wireless transmit/receive units (WTRUs) for training the one or more ML models. The service response is indicative of the one or more WTRUs.

[0008] In an embodiment, the service request is indicative of one or more of: one or more requested analytics services corresponding to the one or more ML models, one or more requested features associated with the one or more ML models, a requested service area, a requested time duration, or a list of a plurality of WTRUs including the one or more WTRUs.

[0009] In an embodiment, the response is indicative of one or more of: one or more available ML models of the one or more ML models, one or more available analytics services of the one or more requested analytics services, one or more available features of the one or more requested features, an available service area, an available time period, or a list of one or more available WTRUs of the plurality of WTRUs.

[0010] In an embodiment, the method includes querying a WTRU management NF. The method includes receiving, from the WTRU management NF, one or more statuses of the one or more WTRUs.

[0011] In an embodiment, the WTRU management NF is: an access and mobility management function (AMF), a session management function (SMF), or a unified data management function (UDM).

[0012] In an embodiment, selecting the one or more FL_NFs includes querying a network repository function (NRF); and receiving, from the NRF, information indicative of the one or more FL_NFs.

[0013] In an embodiment, the one or more FL_NFs include one or more network data analytics functions (NWDAFs) that support VFL.

[0014] In an embodiment, the method includes transmitting, to the AF, an advertisement message indicative of support for VFL. The service request is received in response to the advertisement message.

[0015] In an embodiment, the method includes selecting a FL_NF of the one or more FL_NFs as a representative FL_NF. The method includes forwarding the service request to the representative FL_NF.

[0016] In one or more embodiments, an apparatus comprising a memory, a transceiver, and a processor is provided. The transceiver and the processor are configured to receive, from an AF, a service request for information associated with one or more ML models for VFL. The transceiver and the processor are configured to select, based on the service request, one or more FL_NFs of a plurality of FL_NFs that support the one or more ML models for VFL. The transceiver and the processor are configured to transmit, to the AF, a service response indicative of the selected one or more FL_NFs.

[0017] In an embodiment, the transceiver and the processor are configured to select, based on the service request, one or more WTRUs for training the one or more ML models. The service response is indicative of the one or more WTRUs.

[0018] In an embodiment, the service request is indicative of one or more of: one or more requested analytics services corresponding to the one or more ML models, one or more requested features associated with the one or more ML models, a requested service area, a requested time duration, or a list of a plurality of WTRUs including the one or more WTRUs.

[0019] In an embodiment, the response is indicative of one or more of: one or more available ML models of the one or more ML models, one or more available analytics services of the one or more requested analytics services, one or more available features of the one or more requested features, an available service area, an available time period, or a list of one or more available WTRUs of the plurality of WTRUs.

[0020] In an embodiment, the transceiver and the processor are configured to query a WTRU management NF. The transceiver and the processor are configured to receive, from the WTRU management NF, one or more statuses of the one or more WTRUs.

[0021] In an embodiment, the WTRU management NF is: an AMF, an SMF, or a UDM.

[0022] In an embodiment, selecting the one or more FL_NFs includes querying a NRF and receiving, from the NRF, information indicative of the one or more FL_NFs.

[0023] In an embodiment, the one or more FL_NFs include one or more NWDAFs that support VFL.

[0024] In an embodiment, the transceiver and the processor are configured to transmit, to the AF, an advertisement message indicative of support for VFL. The service request is received in response to the advertisement message.

[0025] In an embodiment, the transceiver and the processor are further configured to select a FL_NF of the one or more FL_NFs as a representative FL_NF, and forward the service request to the representative FL_NF.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0027] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0028] 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;

[0029] 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;

[0030] 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;

[0031] FIG. 2 illustrates an example process for vertical federated learning according to one or more embodiments; and

[0032] FIG. 3 illustrates an example process for vertical federated learning according to one or more embodiments.

DETAILED DESCRIPTION

[0001] The following acronyms may be referred to in the description that follows:

5GC	5G Core Network
5GS	5G System
NEF	Network Exposure Function
AMF	Access and Mobility Management Function
AUSF	Authentication Server Function
CP	Control Plane
DL	Downlink
DN	Data Network
DNN	Data Network Name
FL_NF	Federated Learning Network Function
NEF	Network Exposure Function
NF	Network Function
PCF	Policy Control Function
(R)AN	(Radio) Access Network
SMF	Session Management Function
TA	Tracking Area
UDM	Unified Data Management
UL	Uplink
UPF	User Plane Function
NWDAF	Network Data Analytics Function
VFL	Vertical Federated Learning
HFL	Horizontal Federated Learning

[0033] 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 discrete Fourier transform Spread OFDM (ZT-UW-DFT-S-OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0034] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network (CN) 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a station (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.

[0035] 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, 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 NodeB, an eNode B (eNB), a Home Node B, a Home eNode B, a next generation NodeB, such as a gNode B (gNB), a new radio (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.

[0036] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio

network controller (RNC), relay nodes, and the like. 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. .

[0037] 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).

[0038] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed Uplink (UL) Packet Access (HSUPA).

[0039] 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).

[0040] 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 NR.

[0041] 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).

[0042] 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.

[0043] 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.

[0044] The RAN 104 may be in communication with the CN 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. 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 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 and/or the CN 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the

RAN 104, which may be utilizing a NR radio technology, the CN 106 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0045] The CN 106 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 or a different RAT.

[0046] 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.

[0047] 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.

[0048] 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), 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.

[0049] 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.

[0050] 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.

[0051] 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.

[0052] 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).

[0053] 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.

[0054] 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.

[0055] 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, a humidity sensor and the like.

[0056] 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 DL (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 DL (e.g., for reception)).

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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 (PGW) 166. While 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.

[0061] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c 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.

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] In representative embodiments, the other network 112 may be a WLAN.

[0067] 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 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.

[0068] 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. 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.

[0069] 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.

[0070] 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).

[0071] 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 (MTC), 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).

[0072] 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, all available frequency bands may be considered busy even though a majority of the available frequency bands remains idle.

[0073] 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.

[0074] FIG. 1D 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 NR 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.

[0075] The RAN 104 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 104 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).

[0076] 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 a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0077] 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.

[0078] 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, DC, 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.

[0079] The CN 106 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 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.

[0080] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 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 protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area,

termination of non-access stratum (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 MTC access, and the like. The AMF 182a, 182b may provide a control plane function for switching between the RAN 104 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.

[0081] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 106 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 106 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 DL data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0082] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 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 184a, 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 DL packets, providing mobility anchoring, and the like.

[0083] The CN 106 may facilitate communications with other networks. 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. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local 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.

[0084] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 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.

[0085] 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 performing testing using over-the-air wireless communications.

[0086] 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.

[0087] A network data analytics function may provide one or more statistics and/or one or more predictions based on a request from an entity. Examples of information that the network data analytics function may provide include the one or more statistics and the one or more predictions on gNB status information, gNB resource usage, and/or WTRU communication and mobility performance in an area of interest etc. A target of such analytics may comprise a single WTRU, a group of WTRUs, or any WTRU that may be in an area of interest. The network data analytics function may be provided to characterize a load in one or more network functions and/or one or more network slices, the one or more predictions and/or the one or more statistics associated with WTRU mobility, an expected WTRU behavior, and an observed service experience at multiple levels, such as on a per network slice, for a particular application, or for a particular application over a particular access type (e.g., radio access technology (RAT) access type and/or one or more channel frequencies etc.).

[0088] Third generation partnership project (3GPP) provides how a network data analytics function (NWDAF), including a model training function, may leverage a federated learning (FL)

technique to train a machine learning (ML) model. For horizontal federated learning (HFL), every NWDAF enabled for federated learning registers to a network repository function (NRF) with corresponding network function (NF) profile, information for supported analytics service (e.g., an analytics identifier (ID) etc.), address information of the NWDAF, corresponding service area, and/or corresponding capability for federated learning etc. The information may be stored in the NRF and may be utilized to find a proper NWDAF function to join a specific federated learning for one or more analytics services with one or more candidate ML models and/or a requested service area.

[0089] A model filter may be utilized to indicate one or more conditions when an ML model is requested for the one or more analytics services and the target of the ML model, such as one or more specific WTRUs, a group of WTRUs, and/or any WTRU etc.

[0090] For the HFL, an FL server NWDAF and an FL client NWDAF may be utilized. When an application function (AF) is interested in an analytics service, the AF may request a federated learning ML model from the FL server NWDAF. The request may include a required accuracy of the ML model, the service area, one or more types of data source (e.g., the one or more NFs etc.) from which the NWDAF may collect data for local model training, and/or a time period of interest etc. The FL server NWDAF may discover and select a proper FL client NWDAF for the requested analytics service. The FL server NWDAF may provide, to the FL client NWDAF, a local ML model, and request the FL client NWDAF to perform the local model training. Each FL client NWDAF may collect corresponding local data, perform local model training with the corresponding local data, and report an interim local ML model information to the FL server NWDAF. The FL server NWDAF may update a global ML model based on the aggregated local ML models and provide a proper global ML model for the requested analytics service.

[0091] One or more artificial intelligence (AI)/ML services involving multiple domain data may be beneficial as the one or more AI/ML services may provide a better result with greater efficiency than single domain data. As an example, one or more applications in a WTRU may receive one or more benefits from a cross-domain AI/ML service that uses various mobile network information to represent one or more user conditions. The AI/ML service may utilize the WTRU location, WTRU network (NW) status, and/or WTRU NW experience in some configured area and at a specified time and/or time window.

[0092] In an example, due to strengthened privacy protection policy of one or more operators and/or one or more governments, privacy-sensitive data acquired at the mobile network may not be directly available to a third party application. In an example, as an alternative, vertical federated learning (VFL) may be utilized between the third party application and a mobile operator.

[0093] The vertical federated learning technique is a collaborative ML model among multiple independent training entities and each entity may use corresponding dataset, which may have different features. For example, for a given sample, one or more features may only be available in some of the training entities. For vertical federated learning between the AF and the 5GC network, the 5GC may utilize one or more data features acquired in the mobile network for training a local model in the 5GC, and the local model may be utilized to develop a global ML model in the AF.

[0094] Some coordination between the 5GC and the AF may be required to support the development of the global ML model requested by the AF via the vertical federated learning involving the 5GC and the AF. For example, the AF may need to determine a possible local ML model and manage a performance of the vertical federated model. The AF may need to determine whether one or more analytics services with the ML model are available for vertical federated learning and whether the federated learning may provide an expected performance.

[0095] The 5GC may advertise the support for VFL to the AF. The advertisement may be informed by signaling (e.g., by transmitting an advertisement message) between the 5GC and the AF, and/or via pre-configuration (e.g., during service level agreement). The advertisement may include analytic service information available for federated learning. The advertisement message may include information associated with one or more supported ML models for federated learning. In an example, the one or more supported ML models may be identified by corresponding one or more model IDs, and the advertisement may include a list of indices and/or model IDs associated with the one or more ML models that the 5GS supports. The advertisement may include a list of features available for data collection to be used as an input to the one or more ML models training and verification. Examples of one or more features include but are not limited to quality of service (QoS) parameters, WTRU status, and/or packet data unit (PDU) session status etc.

[0096] The advertisement (e.g., the advertisement message) may include an area information indicative of an area where the one or more analytics services and/or the one or more ML models are available. The area may be associated with one or more cell sites (e.g., cell ID), one or more registration areas, and/or one or more tracking areas etc. The area may be associated with a geographical zone, which may be defined by a geofence configuration, for example.

[0097] The advertisement (e.g., the advertisement message) may include network slice information to inform that one or more network slices are available and/or authorized for federated learning between the 5GC and the AF. The network slice may be different depending on the area of interest. The network slice information may be a network slice selection assistance information (NSSAI).

[0098] In an example, for each analytic service information, associated information may be provided, such as but not limited to the one or more supported ML models, the list of one or more features, and/or the area information etc. Similarly, for each network slice considered, the advertisement information (e.g., the advertisement message) may include e.g., information on supported analytics, the corresponding one or more supported ML models, and/or the list of one or more features, etc.

[0099] The one or more features may be supported at various levels. For example, different statistics may be provided per WTRU level, per cell level, and/or per tracking area level etc. Different features may use the same input data, and process the data in different manners, e.g., the data may be averaged for sampling ratio, the data may be quantized at some granularity, etc. In an example, one or more feature samples may need to be linearly independent so that the one or more features are considered to be of additional value to the analytics of interest (e.g., a feature X and feature 2X are linearly dependent; 2X may not provide additional value if X feature samples are provided).

[0100] In an example, based on advertisement information (e.g., the advertisement message) and other information such as one or more pre-configured parameters and policies, the AF may decide to join a vertical federated learning with the 5GC.

[0101] The 5GC may be configured to transmit the advertisement (e.g., the advertisement message) to the AF based on various factors. In an example, the AF may have previously subscribed to a network exposure function (NEF) to be notified when there is new and relevant VFL information and may be subscribed to receive the advertisement information. In an example, the AF that is not interested in performing VFL with the 5GC may not have subscribed to receive such advertisements.

[0102] Based on one or more configured parameters or policies, the 5GC may have information about one or more applications and/or AFs that may request to receive the advertisement information (or which AFs have subscribed to the advertisement), and the one or more associated parameters for transmitting the advertisement message. In an example, a periodicity may be configured and a period may be used by the NEF to decide when to transmit the advertisement. For example, the period may be specific per AF, or the same for all AFs (i.e., one period configured per NEF). Authorization information related to the AF may be used by the NEF, such as which analytics the AF is authorized to use with the 5GC in VFL. The NEF may determine whether to transmit and when to transmit the advertisement message to a specific AF, e.g., if the AF is not authorized to use certain analytics in VFL with the 5GC, then the NEF may not transmit the advertisement for the analytic to the AF.

[0103] When VFL is requested to the 5GC, the AF may request the information to determine which ML model is to be provisioned with the 5GC for federated learning. The request may include one or more of: information on one or more requested analytics service, one or more candidate ML models for the one or more requested analytic services, a list of one or more features to be used in the requested ML model (e.g., as input data and/or as labels), a requested service area information, a specific time or a time duration, a list of one or more candidate WTRUs, a minimum or a maximum number of WTRUs to use VFL with (as the WTRUs may be considered as samples), and/or a list of network slices of interest (e.g., S-NSSAIs) etc.

[0104] For vertical federated learning, the local 5GC trained ML model and the global AF ML model may need to be compatible so they can be integrated, and the feature set used in the local ML model training in the 5GC may need to be aligned with the AF.

[0105] When some features requested by the AF cannot be supported in the 5GC, it may be desirable to inform the AF so that the AF may consider the available features for determining the global ML model and the local ML model for vertical federated learning.

[0106] For vertical federated learning, it may be necessary to align one or more samples which are used in the global ML model and the local ML model, e.g., coordination between the 5GC and the AF regarding how a sampling is performed for the one or more WTRUs, one or more specific areas, and/or a granularity (e.g., per cell site, per geographical area, and/or per tracking area etc.). A sampling ratio of the data may be shared between the 5GC and the AF. The sampling ratio may be e.g., a number of the one or more WTRUs selected to be the one or more candidate WTRUs for the VFL operation per serving area and/or per geographical area etc. The sampling ratio may be e.g., a number of PDU sessions to be used as the one or more samples per WTRU and/or per service area etc. The sampling ratio may be e.g., the time period used to perform time sampling and recover data for this sample (e.g., collect instantaneous bit rate for the PDU session of WTRU every 1 sec etc.).

[0107] If the vertical federated learning is for the one or more samples of the list of one or more WTRUs and/or the one or more requested analytics services for vertical federated learning are targeted for some specific area and/or some time period, the AF may include, in the request, the list of one or more WTRUs, the requested service area information and/or time condition etc. The request may be sent to the 5GC NF (e.g., the NEF and/or the NWDAF etc.).

[0108] When the 5GC NF receives the request for the information related to the ML model provisioning, the 5GC NF may check the availability of the one or more ML models for the one or more requested analytics services with the one or more requested features, service area and/or the list of WTRUs. In an example, the ML model may be available if certain 5GC functions such as the NWDAF

may train this type of ML model, using the feature list of interest, the service area, and/or the list of one or more WTRUs, while providing a certain accuracy threshold to the AF. A certain ML model may not be available if the 5GC cannot train the ML model with the desired accuracy (e.g., due to the lack of number of WTRUs in the service area of interest).

[0109] Upon receiving the request, the 5GC NF (e.g., the NEF and/or NWDAF etc.) may transmit a request to one or more other 5GC NFs (e.g., one or more 5GC management NFs such as but not limited to the AMF, the SMF, and/or the UDM, etc.) to check an availability of the one or more WTRUs and the status of the WTRUs (e.g., the NAS status, the PDU session status, and/or the service area, etc.) in the list of one or more candidate WTRUs.

[0110] If the list of one or more candidate WTRUs is not provided in the request from the AF, the 5GC NF (e.g., the NEF and/or the NWDAF etc.) may determine the list of one or more WTRUs which are available to get data related to the one or more features at the requested service area and/or the time period. The 5GC NF (e.g., the NEF and/or NWDAF etc.) may select the number of WTRUs from the determined list of the one or more candidate WTRUs based on minimum and/or maximum number of WTRUs that the AF may have provided.

[0111] Among the list of one or more features for the requested ML model, the 5GC NF (e.g., the NEF and/or NWDAF etc.) may check whether the data collection is available or not for the one or more features in the list of one or more features for the requested ML model by requesting other 5GC NFs handling the collection of data associated with the one or more features. Based on status of the WTRU (e.g. the NAS status and/or the PDU session status etc.), it may not be possible to collect relevant data for certain features (e.g., an error rate for a NAS connection time may not be available for WTRUs that are not registered etc.)

[0112] Depending on the AF request, the 5GC NF (e.g., the NEF and/or NWDAF etc.) may consider the full list of candidate WTRUs, and check what features are available for the analytics of interest for each WTRU. If the AF requests the full list of one or more WTRUs to be involved and a feature is not available for some of the WTRUs (e.g., status of the WTRU etc.), then the 5GC NF (e.g., the NEF and/or the NWDAF etc.) may inform the AF of the one or more features that are commonly available between all the WTRUs in the list.

[0113] Alternatively, the 5GC NF (e.g., the NEF and/or the NWDAF etc.) may select the one or more features to be considered for the analytics of interest, and check, for each feature, which WTRUs are available for collection of data associated with the feature. The 5GC NF may then check which WTRUs are common to all the features requested, and if the number of WTRUs satisfies the AF requirement (e.g., a minimum number of WTRUs is available etc.), then the 5GC NF (e.g., the

NEF and/or the NWDAF etc.) may provide the full list of one or more features together with the one or more available WTRUs to be part of the feature data collection for VFL.

[0114] As a response to the information request, the 5GC NF (e.g., the NEF and/or the NWDAF etc.) may provide updated information for the one or more requested analytics services and/or the one or more ML models. The response may include one or more of: an indication of whether the one or more requested ML models for the one or more requested analytics services are available, a list of one or more available ML models for the one or more requested analytics services, a list of one or more available features for the one or more available ML models (as input data and/or as labels), an updated service area information and/or a time condition, if there is any update, the list of one or more WTRUs available for data collection for the requested features, a list of one or more NFs to be involved for local ML model training with corresponding addresses and/or ID information, a list of one or more authorized and/or available network slices (e.g., S-NSSAIs) that are suitable to host VFL, and the accuracy level that the 5GC may achieve using one or more desired ML models and the one or more available features and WTRUs. In an example, different accuracy may be provided for different ML models and/or depending on the one or more features to be used and the number of available samples and/or WTRUs.

[0115] In one example, one or more new 5GC NFs may be defined in the 5GS to support the ML model training (ML_NFs). The one or more ML_NFs may be dedicated to the ML model training. The AF may then communicate with the one or more ML_NFs directly, share the ML model for local training, receive a trained ML model, provide feedback, and/or update the ML model (e.g., if the AF is trusted and/or authorized to obtain such information from the one or more ML_NFs) etc. In case a single 5GC NF, such as the NEF and/or the NWDAF may be in charge of interacting with the AF for VFL, the one or more ML_NFs involved in VFL may be hidden from the AF (e.g., if the AF is untrusted and/or not authorized to obtain the information about the NFs).

[0116] During vertical federated learning, one or more results of the local ML training in the 5GC may be shared with the AF and, based on the one or more results, the AF may update the local ML model (with or without updated features) and request the local ML model training with the updated ML model. When the one or more results of the local ML training are shared, the performance metric of the ML training may be provided together (e.g. the accuracy of the one or more training results).

[0117] When the AF shares the ML model for initiating vertical federated learning with the 5GC, the AF may include the requested performance metrics. When the requested performance metrics are not met after some period of the local ML training, the 5GC may inform the AF so that the AF may determine whether to stop the VFL or to update a VFL strategy (e.g., using the updated ML

model for local training, one or more updated features, an updated list of one or more WTRUs, updated service area and/or time period etc.).

[0118] A method for vertical federated learning via a direct connection with the one or more NFs includes, in one example, the NEF may advertise the support of VFL to the AF, including the one or more supported analytics services for vertical federated learning and the one or more supported ML models with the one or more features. The AF may transmit a request for information on the one or more ML models for VFL, including the one or more requested analytics services, one or more candidate ML models, a list of one or more requested features, and/or a list of one or more candidate WTRUs etc. Based on the request, the NEF may discover one or more 5GC FL_NFs that may be able to support the requested VFL, e.g., the one or more requested analytics services, the one or more candidate ML models, and/or the one or more features from the list of one or more requested features etc. The NEF may select the one or more FL_NFs to support the request. The FL_NF may be a NWDAF. The NEF may transmit a response to the AF, including the one or more supported ML models, the list of one or more supported features, and the updated list of one or more candidate WTRUs. The AF may transmit a request for VFL initiation to the NEF, including local ML model information with the one or more features and the list of one or more WTRUs. The NEF may forward the request to the one or more selected FL_NFs.

[0119] Referring now to FIG. 2, an example process 200 for vertical federated learning is shown according to one or more embodiments. The process 200 may be performed using an AF 202, an NEF 204, an FL_NF 206, and a NF 208. The AF 202 may be in direct connection with the one or more 5GC NFs including the NEF 204.

[0120] At 211, the NEF 204 transmits the advertisement message which includes a capability of vertical federated learning of the 5GC. The advertisement message may include analytics service information available for federated learning, one or more supported ML models' information for federated learning, the list of one or more features available for data collection as input for the ML model training and verification, and/or area information (e.g., in case the analytics service or some ML models are available only for some area) etc. In the advertisement, the supported ML models' information, the list of one or more features, and/or the area information may be provided per analytic service information.

[0121] In an example, the availability information of vertical federated learning may be configured in the AF 202 by other means (e.g. included at service level agreement for VFL, accessing configuration server for VFL, etc.). The AF 202 may also initiate a query (not shown in FIG. 2) towards

the NEF 204 about one or more VFL models and/or features that are available in the 5GC, and the AF 202 may receive the advertisement as the response.

[0122] At 212, the AF 202 may be triggered to use the one or more analytics services and, based on information acquired in 211, the AF 202 may decide to use vertical federated learning with the 5GC for the one or more analytic services.

[0123] At 213, once the AF 202 decides to use VFL with the 5GC, the AF 202 may transmit the service request for information about the one or more ML models for VFL. The service request may include requested analytics service information, the one or more candidate ML models for the one or more requested analytics services, and/or the list of one or more features to be used in the one or more requested ML models (as input data and/or as labels) etc. The AF 202 may include the requested service area information and/or time condition in the service request, if the requested analytic service and/or the one or more ML models are for some specific service area and/or time period. If the requested features are related to data associated with the one or more WTRUs (e.g., a NAS status of WTRU, a PDU session status of a WTRU, etc.), the list of one or more candidate WTRUs and/or one or more conditions for selection of the one or more WTRUs (e.g., active or idle state, 3GPP RAT or N3GPP RAT, a NW slice or DNN, etc.) may also be included.

[0124] At 214, after receiving the service request for information about the one or more ML models for VFL, the NF (here, the NEF 204) which is responsible for information gathering for vertical federated learning, may query the NRF to discover the one or more FL_NFs. The FL_NF 206 may be, e.g., a NWDAF that supports federated learning (FL_NWDAF). The FL_NWDAF may support the one or more the requested analytic services, the one or more ML models in the one or more candidate ML models, the list of one or more supported features for the supported ML model.

[0125] At 215, when the list of one or more candidate WTRUs is included in the request in 213, the NEF 204 may query the 5GC NFs (e.g., the AMF, the SMF, and/or the UDM etc.) to check the status of the one or more WTRUs (e.g., the NAS status, an access network status, the PDU session status, the service area, and/or the cell ID, etc.) and determine whether the dataset associated with the one or more WTRUs for the one or more requested features is available. In an example, when the one or more WTRUs are unregistered in the NW, the PDU session status of the one or more WTRUs is not available. When the AF 202 includes the list of one or more WTRUs to be selected as the one or more candidate WTRUs, a set of WTRUs satisfying the one or more conditions may be considered by the NEF 204. The NEF 204 may determine whether a set of requested features are available or some of the features are not available (for example, based on the requested service area and/or the requested time period, and/or the requested list of WTRUs etc.).

[0126] If the list of candidate WTRUs is not included in the request, the NEF 204 may query the 5GC NF associated with the one or more requested features, the list of one or more WTRUs served by the NF at the requested service area. The NEF 204 may select the list of one or more WTRUs which are commonly served by the NFs involved for data collection of the one or more features and the NEF 204 may verify the statuses of the set of WTRUs belonging to the list of one or more WTRUs (e.g. the NAS status, the access network status, the PDU session status, the service area, and/or the cell ID, etc.) to verify if the set of WTRUs satisfy the one or more conditions for selection of the one or more WTRUs. Based on the verification result, the NEF 204 may derive the list of one or more WTRUs of which data for the one or more requested features are collected and use the list for training the ML model.

[0127] At 216, the NEF 204 transmits the service response for information about the one or more ML models for VFL to the AF 202 as the response of the request received in 213. The service response may include an indication whether the one or more requested ML models for the one or more requested analytics service are available, the list of one or more available ML models for the one or more requested analytic services, the list of one or more available features for the one or more available ML models (as input data and/or as labels), the updated service area information and/or the time condition, the list of one or more WTRUs available for data collection for the one or more features. And the NEF 204 may include the list of one or more FL_NFs to be involved for the local ML model training with their addresses and/or ID information. When the list of one or more FL_NFs is included in the request, the service response may include the list of the one or more WTRUs available for data collection for the one or more features for each FL_NF.

[0128] At 217, based on the service response, the AF 202 may determine the ML model for the requested analytics service, the local ML model to be used for VFL at the 5GC and the list of one or more features to be used for the local ML model. Associated to the selected list of one or more features, the AF 202 may down-select the one or more WTRUs to be involved for VFL from the list of one or more WTRUs received in 216.

[0129] At 218, the AF 202 may initiate vertical federated learning by transmitting the service request for initiating VFL including information on the local ML model for local training, the list of one or more features (as the input data and/or as the label etc.) and/or the list of one or more WTRUs etc. The AF 202 may include the requested performance metric (e.g., a required accuracy of the trained ML model). The AF 202 may request to share the interim result of the local ML model training and the performance metric of the result.

[0130] The AF 202 may communicate with each FL_NF separately for sharing the ML model for the local training, upload an interim trained ML model, upload a final trained ML model, receive feedback from the AF 202, and download an updated ML model for local training.

[0131] When sharing an ML model for local training, the AF 202 may provide information about the server (e.g. an IP address and/or a protocol, etc.) from which the 5GC may download the ML model for local training, upload the interim trained ML model, upload final trained ML model, receive feedback from the AF 202, and download the updated ML model for local training. When list of one or more FL_NFs is provided in 216, the AF 202 may provide different server address per FL_NF.

[0132] At 219, after receiving initiation of VFL, each FL_NF performs data collection for the one or more requested features for the list of one or more WTRUs which belong to the FL_NF and performs the local ML training using the data.

[0133] At 220, based on the request from the AF 202, each FL_NF may share corresponding interim result of the local ML training with one or more performance metrics of the interim result.

[0134] At 221, based on the interim result, the AF 202 may update the local ML model (with or without updated features) and request the local ML model training with the updated ML model. When the requested performance metric is not met after some period of local ML training, the AF 202 may determine whether to stop the VFL and/or update the vertical federated learning strategy (e.g., the updated ML model for local training, one or more updated features, an updated WTRUs list, the updated service area and/or the time period etc.).

[0135] The AF 202 and the one or more FL_NFs may repeat procedure of 209 and 220, 221 until the requested ML performance metric is met.

[0136] At 222, the AF 202 collects the trained local ML model and updates the global ML model.

[0137] In another example, a representative FL_NWDAF may be defined. A representative FL_NWDAF is an FL_NF which is in charge of interacting with the AFs and receives the requests related to the vertical federated learning services.

[0138] When the service request for information on the one or more ML models for VFL is received from the AF, the representative FL_NWDAF may identify the other 5GC FL_NWDAFs that may support the requested federated learning, and select the appropriate FL_NWDAFs. The representative FL_NWDAF may determine the one or more supported ML models, features, and/or the list of one or more WTRUs to be involved in the local model training. The representative FL_NWDAF may keep the context of the one or more available FL_NFs for the one or more analytics services and the requested ML model with the one or more features.

[0139] When receiving the service request for initiating VFL, the representative FL_NWDAF may coordinate with the one or more FL_NFs for downloading the local ML model and the data collection, training the local model, and monitoring the performance of the local training. The representative FL_NWDAF may interact with the AF for updating vertical federated learning strategy (e.g., the updated ML model for local training, the updated features, the updated WTRUs list, the updated service area and/or time period etc.).

[0140] A method for VFL using a representative FL_NWDAF includes, in an example, the representative FL_NWDAF receiving, from the AF, the service request for information about the one or more ML models, including the one or more requested analytics services, the one or more candidate ML models, the list of one or more features, and/or the list of one or more candidate WTRUs etc. The representative FL_NWDAF may discover and select the one or more FL_NFs supporting the one or more analytics services, the one or more candidate ML models, and/or the one or more features in the requested list of features and may select the one or more FL_NFs for the one or more requested analytics services with the one or more supported ML models, the one or more supported features, and/or the list of one or more candidate WTRUs etc. The representative FL_NWDAF may transmit the service response to the AF including the one or more supported ML models, the one or more supported features, and the list of one or more candidate WTRUs (possibly updated based on the availability of the WTRU data in the one or more selected FN_NFs). The representative FL_NWDAF may receive, from the AF, the service request for initiation of VFL including information on the local ML model with the one or more features and the list of one or more candidate WTRUs. The representative FL_NWDAF may forward the request for VFL initiation to the one or more selected FL_NFs, including the local ML model. The representative FL_NWDAF may receive the interim results of the local ML model training from the one or more FL_NFs and transmit a collated interim result of the local ML model training to the AF. The representative FL_NWDAF may receive feedback from the AF about the interim result and an updated VFL strategy. The representative FL_NWDAF may forward the updated VFL strategy to the one or more FL_NFs.

[0141] Referring now to FIG. 3, an example process 300 for VFL is shown according to one or more embodiments. The process 300 may be used in a representative FL_NWDAF. The process 300 may be performed using an AF 302, a NEF 304, a representative FL_NWDAF 306, a FL_NF 308, and a NF 310.

[0142] At 311, the NEF 304 may transmit the advertisement message, which includes the capability of vertical federated learning of the 5GC. The advertisement message may include the analytics service information available for federated learning, the supported ML models' information for federated learning, the list of one or more features available for data collection as input for the ML

model training and verification, and/or the area information, if the analytics service and/or some ML models are available only for some area. In an example, the information about the one or more supported ML models, the list of one or more features, and/or the area information may be provided per analytic service information etc.

[0143] The availability information of vertical federated learning may be configured by other means (e.g., included at service level agreement for VFL, accessing a configuration server for VFL, etc.).

[0144] At 312, the AF 302 may be triggered to use the one or more analytics services and, based on information acquired in 311, the AF 302 may decide to use vertical federated learning with the 5GC for the one or more analytics services.

[0145] At 313, once the AF 302 decides to use VFL with the 5GC, the AF 302 may transmit the service request for information on the one or more ML models for VFL. The service request may include the one or more requested analytics service's information, the one or more candidate ML models for the requested analytic service, and/or the list of one or more features to be used in the requested ML model (as input data and/or as labels) etc. The AF 302 may include the requested service area information and/or the time condition if the one or more requested analytic services and/or the one or more ML models are for some specific service area and/or time period etc. If the one or more requested features are related to data of the one or more WTRUs (e.g., the NAS status of the WTRU, the PDU session status of the WTRU, etc.), the list of one or more candidate WTRUs may be included, with the one or more conditions for selection of the one or more WTRUs (e.g. active or idle state, 3GPP RAT or N3GPP RAT, a NW slice and/or DNN, etc.).

[0146] Upon receiving the service request for the information on the one or more ML models for VFL, the NEF 304 selects the representative FL_NWDAF 306 for handling the service request from the AF 302 and forwards the service request to the representative FL_NWDAF 306.

[0147] At 314, after receiving the service request for information on the one or more ML models for VFL, the representative FL_NWDAF 306 may query the NRF to discover the FL_NF 308 (here, the FL_NWDAF 308, i.e., the NWDAF which supports federated learning) which supports the one or more requested analytics services, the one or more ML models in the one or more candidate ML models, and/or the one or more supported features for the one or more supported ML models. There may be more than one FL_NFs supporting the request.

[0148] At 315, when the list of one or more candidate WTRUs is included in the request in 313, the representative FL_NWDAF 306 may query the relevant 5GC NF (e.g. the AMF, the SMF, and/or the UDM etc.) to check the status of the one or more WTRUs (e.g. the NAS status, the access

network status, the PDU session status, the service area, and/or the cell ID, etc.) and determine whether a dataset related to the one or more WTRUs for the requested features is available. For example, when the one or more WTRUs are unregistered in the NW, the one or more PDU session statuses of the one or more WTRUs are not available. When the AF 302 includes the one or more conditions for the one or more WTRUs to be selected as the one or more candidate WTRUs, the one or more WTRUs satisfying the one or more conditions may be considered and the representative FL_NWDAF 306 may determine whether the one or more requested features are available and/or some of features are not available (for example, in the requested service area and/or the time period, and/or with the list of one or more requested WTRUs etc.).

[0149] If the list of one or more candidate WTRUs is not included in the request, the representative FL_NWDAF 306 may query the FL_NF 308, for the one or more available features and/or for the list of one or more WTRUs served by the FL_NF 308. The NEF 304 may check the one or more statuses of the one or more WTRUs in the list of one or more WTRUs (e.g. the NAS status, the access network status, the PDU session status, the service area, and/or the cell ID, etc.). Based on the status information, the representative FL_NWDAF 306 may derive the list of one or more WTRUs for which data for the one or more requested features is collected and used for training the ML model.

[0150] When selecting the one or more WTRUs to be involved in training the ML model, the one or more WTRUs having the same status (e.g., active or idle status, per NW slice, per DNN, and/or per RAT etc.) may be selected for the one or more requested features.

[0151] At 316, the representative FL_NWDAF 306 may transmit the service response to the AF 302 as the response to the request received in 313 via the NEF 304. The service response may include the indication on whether the one or more requested ML models for the one or more requested analytics service are available, the list of one or more available ML models for the one or more requested analytics services, the list of one or more available features for the one or more available ML models (as the input data and/or as labels etc.), the updated service area information, the updated time condition, and/or the list of one or more WTRUs available for data collection for the one or more features etc.

[0152] The representative FL_NWDAF 306 may save the list of one or more FL_NFs that may be involved for the local ML model training for the one or more requested analytics services, the one or more requested ML models with the one or more features, and/or the list of one or more WTRUs per FL_NF etc.

[0153] At 317, based on the service response, the AF 302 may determine the one or more ML models for the one or more requested analytics services, the local ML model to be used for VFL at the 5GC, and the list of one or more features to be used for the local ML model. Based on the selected list of features, the AF 302 may down-select the one or more WTRUs to be involved for VFL from the list of WTRUs received in 316.

[0154] At 318, the AF 302 may initiate vertical federated learning and share the ML model for local training with the list of one or more features (as input data and/or as label) and the list of one or more WTRUs with the representative FL_NWDAF 306 via the NEF 304. The AF 302 may include a requested performance metric (e.g. a required accuracy of the trained ML model). The AF 302 may request the interim result of the local ML model training and the performance metric of the result to be shared.

[0155] The AF 302 may provide a server address from which the 5GC may download the one or more ML models for local training, upload the one or more interim trained ML models, upload the one or more final trained ML models, receive feedback from the AF 302, and/or download the one or more updated ML models for local training etc.

[0156] At 319, after receiving the request for initiation of VFL, the representative FL_NWDAF 306 may determine the one or more FL_NFs to be involved in the requested federated learning with the local ML model (for example, based on the managed context at 316). The representative FL_NWDAF 306 may coordinate with the one or more FL_NFs to download the local the ML model (e.g., sharing the server address that was shared by the AF 302, sharing the server address managed by the representative FL_NWDAF 306 for communication with the one or more FL_NFs, and/or sharing the information by service based interface etc.). The representative FL_NWDAF 306 may inform the one or more FL_NFs a subset of the list of one or more WTRUs to be used as samples for the local ML model training.

[0157] Each FL_NF performs data collection for the one or more requested features for the list of one or more WTRUs which belongs to the FL_NF and each FL_NF performs the local ML training using the data.

[0158] At 320, based on the request from the AF 302, the representative FL_NWDAF 306 may collate the interim result of the local ML training and the one or more performance metrics of the interim result and share the one or more results (e.g. the interim result and/or the one or more performance metrics) with the AF 302. The representative FL_NWDAF 306 may build the merged interim local ML model from the collated results and share the merged interim local ML model with the training results with the AF 302.

[0159] At 321, based on the interim results received, the AF 302 may update the local ML model (with or without updated features) and request for the local ML model training with the updated ML model. When the requested performance metric is not met after some period of the local ML training, the AF 302 may determine whether to stop the VFL or to update the vertical federated learning strategy (e.g., using the updated ML model for local training, the one or more updated features, the updated list of one or more WTRUs, the updated service area and/or the time period etc.).

[0160] The AF 302 and the representative FL_NWDAF 306 may repeat the procedure of 319 and 320, 321 until the requested ML performance metric is met.

[0161] At 322-325, the AF may collect the trained local ML model and update the global ML model.

[0162] In an example, a method for vertical federated learning NF selection guide from the AF is disclosed. The AF may provide vertical federated learning guidance to the NEF to assist with the FL_NF selection. In one example, the VFL AF and the 5GC NF (e.g. the NEF and/or the NWDAF etc.) may collaborate to select the one or more NFs for the features from the AF. In an example, some features may present in multiple NFs. In an example, the WTRU ID may be in different form in different NF; e.g., the WTRU ID may be represented by a MAC address, an IP address, a global ID, a temporary ID, an application ID, and the user location may come from an LMF, a GMLC, and/or an SL positioning server WTRU, etc.

[0163] The VFL AF may transmit the 5GC assistance information to help to select and/or narrow down to right NF candidates that are optimal in the VFL training, such as but not limited to specific location area, one or more NFs in specific slice, one or more RANs along a specific highway, one or more NFs with specific HW, SW, capabilities, and/or manufactures, etc.

[0164] In case some features are duplicated in multiple NFs and may have different values for e.g., range, accuracy and/or may have conflicting values, for example, a user status may be active in one NF, but may be idle in another NF due to various reasons, such as the sample time difference, the AF may transmit the criteria for feature alignment and/or data collection to the 5GC NF (e.g. the NEF, the FL_NWDAF etc.), such as but not limited to e.g., the time period, the service area, an allowed NW slice, and/or an access NW information etc.

[0165] 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 computer-readable media include

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

CLAIMS

What is Claimed is:

1. A method performed by a network function (NF), the method comprising:
 - receiving, from an application function (AF), a service request for information associated with one or more machine learning (ML) models for vertical federated learning (VFL);
 - selecting, based on the service request, one or more federated learning network functions (FL_NFs) of a plurality of FL_NFs that support the one or more ML models for VFL; and
 - transmitting, to the AF, a service response indicative of the selected one or more FL_NFs.
2. The method of claim 1, further comprising:
 - selecting, based on the service request, one or more wireless transmit/receive units (WTRUs) for training the one or more ML models, wherein the service response is indicative of the one or more WTRUs.
3. The method of claim 2, wherein the service request is indicative of one or more of:
 - one or more requested analytics services corresponding to the one or more ML models,
 - one or more requested features associated with the one or more ML models,
 - a requested service area,
 - a requested time duration, or
 - a list of a plurality of WTRUs including the one or more WTRUs.
4. The method of claim 3, wherein the response is indicative of one or more of:
 - one or more available ML models of the one or more ML models,
 - one or more available analytics services of the one or more requested analytics services,
 - one or more available features of the one or more requested features,
 - an available service area,

- an available time period, or
 - a list of one or more available WTRUs of the plurality of WTRUs.
5. The method of claim 2, further comprising:
- querying a WTRU management NF; and
 - receiving, from the WTRU management NF, one or more statuses of the one or more WTRUs.
6. The method of claim 5, wherein the WTRU management NF is:
- an access and mobility management function (AMF),
 - a session management function (SMF), or
 - a unified data management function (UDM).
7. The method of claim 1, wherein selecting the one or more FL_NFs includes:
- querying a network repository function (NRF); and
 - receiving, from the NRF, information indicative of the one or more FL_NFs.
8. The method of claim 1, wherein the one or more FL_NFs include one or more network data analytics functions (NWDAFs) that support VFL.
9. The method of claim 1, further comprising:
- transmitting, to the AF, an advertisement message indicative of support for VFL, wherein the service request is received in response to the advertisement message.
10. The method of claim 1, further comprising:
- selecting a FL_NF of the one or more FL_NFs as a representative FL_NF; and
 - forwarding the service request to the representative FL_NF.
11. An apparatus, comprising:
- a transceiver; and
 - a processor, wherein the transceiver and the processor are configured to:
 - receive, from an application function (AF), a service request for information associated with one or more machine learning (ML) models for vertical federated learning (VFL),

select, based on the service request, one or more federated learning network functions (FL_NFs) of a plurality of FL_NFs that support the one or more ML models for VFL, and

transmit, to the AF, a service response indicative of the selected one or more FL_NFs.

12. The apparatus of claim 11, wherein the transceiver and the processor are further configured to:

select, based on the service request, one or more wireless transmit/receive units (WTRUs) for training the one or more ML models, wherein the service response is indicative of the one or more WTRUs.

13. The apparatus of claim 12, wherein the service request is indicative of one or more of:

one or more requested analytics services corresponding to the one or more ML models,

one or more requested features associated with the one or more ML models,

a requested service area,

a requested time duration, or

a list of a plurality of WTRUs including the one or more WTRUs.

14. The apparatus of claim 13, wherein the response is indicative of one or more of:

one or more available ML models of the one or more ML models,

one or more available analytics services of the one or more requested analytics services,

one or more available features of the one or more requested features,

an available service area,

an available time period, or

a list of one or more available WTRUs of the plurality of WTRUs.

15. The apparatus of claim 12, wherein the transceiver and the processor are further configured to:

query a WTRU management NF, and

receive, from the WTRU management NF, one or more statuses of the one or more WTRUs.

16. The apparatus of claim 15, wherein the WTRU management NF is:

an access and mobility management function (AMF),
a session management function (SMF), or
a unified data management function (UDM).

17. The apparatus of claim 11, wherein selecting the one or more FL_NFs includes:

querying a network repository function (NRF); and
receiving, from the NRF, information indicative of the one or more FL_NFs.

18. The apparatus of claim 11, wherein the one or more FL_NFs include one or more network data analytics functions (NWDAFs) that support VFL.

19. The apparatus of claim 11, wherein the transceiver and the processor are further configured to:

transmit, to the AF, an advertisement message indicative of support for VFL, wherein the service request is received in response to the advertisement message.

20. The apparatus of claim 11, wherein the transceiver and the processor are further configured to:

select a FL_NF of the one or more FL_NFs as a representative FL_NF, and
forward the service request to the representative FL_NF.