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Method and apparatus for in-house RF-based collaborative localization with automated data collection

Abstract

A method for localization includes obtaining a request to localize an electronic device within an area, wherein the area includes a set of anchors. The method also includes transmitting a first message to the electronic device and a second message to the set of anchors. the first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device. The method further includes receiving, from the set of anchors, signal information associated with the measurement signal. Additionally, the method includes identifying a location of the electronic device within the area based on the signal information. The method also includes transmitting, to the electronic device, the location of the electronic device within the area.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION AND CLAIM OF PRIORITY (1) This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 63/118,496 filed on Nov. 25, 2020. The above-identified provisional patent application is hereby incorporated by reference in its entirety.

TECHNICAL FIELD
(1) This disclosure relates generally to localizing an electronic device. More specifically, this disclosure relates to in-house RF-based collaborative localization with automated data collection.
BACKGROUND
(2) The use of mobile computing technology has greatly expanded largely due to usability, convenience, computing power, and the like. One result of the recent technological development is that electronic devices are becoming more compact, while the number of functions and features that a given device can perform is increasing, such as localizing a device within an environment. For example, in wireless communication applications, various wireless electronic devices can be located within a given environment. Localizing a wireless electronic device within an environment can be based on comparing the distance between the wireless electronic device to other wireless electronic devices within the environment as identified based on signals transmitted between the wireless devices. However localization may not be possible when there are not enough devices for localization purposes. Additionally, data collection for fingerprinting the environment for localization can be cumbersome.
SUMMARY
(3) This disclosure provides in-house RF-based collaborative localization with automated data collection.
(4) In a first embodiment, a method for localization is provided. The method includes obtaining a request to localize an electronic device within an area, wherein the area includes a set of anchors. The method also includes transmitting a first message to the electronic device and a second message to the set of anchors. the first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device. The method further includes receiving, from the set of anchors, signal information associated with the measurement signal. Additionally, the method includes identifying a location of the electronic device within the area based on the signal information. The method also includes transmitting, to the electronic device, the location of the electronic device within the area.
(5) In another embodiment, an electronic device is provided. The electronic device includes a transceiver and a processor. The processor is configured to obtain a request to localize an electronic device within an area, wherein the area includes a set of anchors. The processor is also configured to transmit a first message to the electronic device and a second message to the set of anchors. The first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device. The processor is further configured to receive, from the set of anchors, signal

information associated with the measurement signal. Additionally, the processor is configured to identify a location of the electronic device within the area based on the signal information. The processor is also configured to transmit, to the electronic device, the location of the electronic device within the area.

(6) In yet another embodiment a non-transitory computer readable medium embodying a computer program is provided. The computer program comprising computer readable program code that, when executed by a processor of an electronic device, causes the processor to: obtain a request to localize an electronic device within an area, wherein the area includes a set of anchors; transmit a first message to the electronic device and a second message to the set of anchors, wherein the first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device; receive, from the set of anchors, signal information associated with the measurement signal; identify a location of the electronic device within the area based on the signal information; and transmit, to the electronic device, the location of the electronic device within the area.

(7) In another embodiment, a method for localization by an electronic device is provided. The method includes transmitting, to a localization system coordinator (LSC) device, a request to receive a localization model with implicit labels, wherein the localization model is generated based on measurement signals received from a set of anchors positioned throughout an area. The method also includes receiving, from the LSC device, the localization model. The method further includes identifying measurements from signals generated by two or more anchors of the set of anchors. Additionally, the method includes identifying a location of the electronic device based on the measurements from the signals and the localization model.

(8) Other technical features may be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

(9) Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document. The term “couple” and its derivatives refer to any direct or indirect communication between two or more elements, whether or not those elements are in physical contact with one another. The terms “transmit,” “receive,” and “communicate,” as well as derivatives thereof, encompass both direct and indirect communication. The terms “include” and “comprise,” as well as derivatives thereof, mean inclusion without limitation. The term “or” is inclusive, meaning and/or. The phrase “associated with,” as well as derivatives thereof, means to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, have a relationship to or with, or the like. The term “controller” means any device, system or part thereof that controls at least one operation. Such a controller may be implemented in hardware or a combination of hardware and software and/or firmware. The functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. The phrase “at least one of,” when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, “at least one of: A, B, and C” includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C.

(10) Moreover, various functions described below can be implemented or supported by one or more computer programs, each of which is formed from computer readable program code and embodied in a computer readable medium. The terms “application” and “program” refer to one or more computer programs, software components, sets of instructions, procedures, functions, objects, classes, instances, related data, or a portion thereof adapted for implementation in a suitable computer readable program code. The phrase “computer readable program code” includes any type of computer code, including source code, object code, and executable code. The phrase “computer

readable medium" includes any type of medium capable of being accessed by a computer, such as read only memory (ROM), random access memory (RAM), a hard disk drive, a compact disc (CD), a digital video disc (DVD), or any other type of memory. A "non-transitory" computer readable medium excludes wired, wireless, optical, or other communication links that transport transitory electrical or other signals. A non-transitory computer readable medium includes media where data can be permanently stored and media where data can be stored and later overwritten, such as a rewritable optical disc or an erasable memory device.
(11) Definitions for other certain words and phrases are provided throughout this patent document. Those of ordinary skill in the art should understand that in many if not most instances, such definitions apply to prior as well as future uses of such defined words and phrases.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:
(2) FIG. **1** illustrates an example communication system in accordance with an embodiment of this disclosure;
(3) FIGS. **2** and **3** illustrate example electronic devices in accordance with an embodiment of this disclosure;
(4) FIG. **4** illustrates an example architecture of a localization system in accordance with an embodiment of this disclosure;
(5) FIG. **5** illustrates a method for a localization system in accordance with an embodiment of this disclosure;
(6) FIG. **6** illustrates an example method of a localization system coordinator (LSC) responding to a request for localization in accordance with an embodiment of this disclosure;
(7) FIG. **7**A illustrates an example method of a LSC determining a location of an electronic device in accordance with an embodiment of this disclosure;
(8) FIG. **7**B illustrates a timing diagram for localizing an electronic device in accordance with an embodiment of this disclosure;
(9) FIG. **8** illustrates a block diagram for partial distributed processing for localization in accordance with an embodiment of this disclosure;
(10) FIG. **9**A illustrates an example method of an LSC coordinating data collection for generating a localization model in accordance with an embodiment of this disclosure;
(11) FIG. **9**B illustrates an example method of associating localization data with implicit labels in accordance with an embodiment of this disclosure;
(12) FIGS. **10**A and **10**B illustrate example diagrams for mapping implicit labels to explicit labels in accordance with an embodiment of this disclosure;
(13) FIG. **11**A illustrates an example method for requesting explicit labels from a user in accordance with an embodiment of this disclosure;
(14) FIG. **11**B illustrates an example method for determining explicit location based on sensor data in accordance with an embodiment of this disclosure;
(15) FIG. **12** illustrates an example method for generating multiple localization models in accordance with an embodiment of this disclosure;
(16) FIG. **13** illustrates an example method for localization by the LSC in accordance with an embodiment of this disclosure; and
(17) FIG. **14** illustrates an example method for localization by the electronic device in accordance with an embodiment of this disclosure.

DETAILED DESCRIPTION

(18) FIGS. **1** through **14**, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably-arranged system or device.

(19) The following documents are hereby incorporated by reference into the present disclosure as if fully set forth herein: (i) IEEE 802.11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications: (2016 revision); and (ii) "OCF Device Specification v2.2.0," Open Connectivity Foundation, July 2020.

(20) An electronic device, according to embodiments of the present disclosure, can include a personal computer (such as a laptop, a desktop), a workstation, a server, a television, an appliance, and the like. In certain embodiments, an electronic device can be a portable electronic device such as a portable communication device (such as a smartphone or mobile phone), a laptop, a tablet, an electronic book reader (such as an e-reader), a personal digital assistants (PDAs), a portable multimedia player (PMP), an MP3 player, a mobile medical device, a virtual reality headset, a portable game console, a camera, and a wearable device, among others. Additionally, the electronic device can be at least one of a part of a piece of furniture or building/structure, an electronic board, an electronic signature receiving device, a projector, or a measurement device. The electronic device can be a wireless access point such as a Wi-Fi router. The electronic device is one or a combination of the above-listed devices. Additionally, the electronic device as disclosed herein is not limited to the above-listed devices and can include new electronic devices depending on the development of technology. It is noted that as used herein, the term "user" may denote a human or another device (such as an artificial intelligent electronic device) using the electronic device.

(21) Radio frequency (RF) signals (such as Wi-Fi signals) can be used for localizing an electronic device within a defined area (environment). Using RF signals for localization can be referred to as fingerprinting. The process of fingerprinting can be used for localizing an electronic device within an area. Generally, fingerprinting is based on a database of measurements of a region of interest (such as a given environment). The measurements can be divided into a grid which is used for matching a current RF signature to points in the database. Various machine learning solutions can be utilized to perform the matching.

(22) Embodiments of the present disclosure take into consideration that localization based on fingerprinting is not practical in a home setting. For example, fingerprinting refers to RF measurements that are taken at fixed nodes, denoted as anchors. Generally access points (such as Wi-Fi gateways) are selected to act as anchors. However, in a typical home, the number of access points is limited, since, depending on the size of the home, one or two access points are needed for providing Wi-Fi coverage throughout the home. Additionally, the access points are spaced throughout the house such that only one or two can be seen at any given location. The number and location of access points is ideal for networking perspective (providing Wi-Fi throughout a home) but provides poor localization services.

(23) Additionally, manual data collection for fingerprinting is not practical in a home. For example, data collection is performed by dividing the environment of interest into a grid and measurements are collected from each point on the grid. This process is laborious, cumbersome, and expensive and often not practical to be performed in a home of each user.

(24) Accordingly, embodiments of the present disclosure describe methods for an RF based localization service. That is, the embodiments of the present disclosure address the limited number of anchors in the environment, and cumbersome task of collecting training data. The embodiments of the present disclosure provide an architecture for performing the localization service in a given environment, such as a person's home. For example, access points that are used as anchors in public venues such as an airport or a mall, are possible since multiple access points can be seen

simultaneously by a device for localization purposes. However, in a home setting, such an assumption is no longer valid, since there are only few access points installed in a house, and in most cases zero or one access point can be seen at a time. Therefore, embodiments of the present disclosure take into consideration that using only access points for anchors for localization could become the performance bottleneck.
(25) Regarding the limited number of anchors in a home, embodiments of the present disclosure recognize that the number of APs are limited, while the number of Wi-Fi capable devices is increasing. As such, for RF-based localization purpose, immobile devices could be used in addition to access points instead of relying solely on access points. An ‘immobile device’ is defined as any device that is moved infrequently (for example, months or years). Some examples of immobile devices include a smart refrigerator, TV, printer, desktop computer, security cameras, and the like. For example, embodiments as disclosed herein expands the number of anchors to include any immobile Wi-Fi-capable devices in the environment. Since the number of Wi-Fi capable devices is increasing, there will be more and more anchors that could be used, and thus the localization performance can continue to improve.
(26) Regarding the cumbersome task of collecting training data, embodiments of the present disclosure recognize that by collecting RF measurements from devices with known location, localization training data can be autonomously collected. The devices can be immobile devices or mobile devices under special circumstances. For example, when a mobile phone is being charged via a cable to an electrical outlet, localization training data can be autonomously collected from the mobile phone. Such automatic data collection can provide implicit labels (such as P1, P2, P3, . . . with no interpretable meaning; they only allow the distinction between different locations). If explicit labels (such as living room, kitchen or bedroom etc.) are desirable, they may be requested from the human user. Because such labels are only needed once after obtaining the dataset (to provide a mapping between implicit label to explicit label, such as, relating the implicit label of P1 to the kitchen, and the like), it places little burden on the human user. It is noted that not all applications use explicit location labels. For example, for applications that target customized experience based on historical usage of the device can operate with implicit location labels (they only need to distinguish different locations).
(27) Regarding the architecture for performing a localization service in a given environment, embodiments of the present disclosure describe several architectures for operating such a location service. For example, location computation can be performed by the anchors (which could be immobile devices or access point) and not at the mobile device using the service. This architecture can provide fast localization as well as allowing devices with low computational power (such as a wearable fitness band) to use the localization service as most computation will be done at the anchors.
(28) Therefore, embodiments of the present disclosure provide systems and methods for coordinating, by one or more anchors selected from the plurality of anchors, distributed data collection and localization model creation from a plurality of anchors and mobile devices. Embodiments of the present disclosure also provide systems and methods for performing semantic/explicit labeling of locations for the model via the data collection.
(29) It is noted that the embodiments disclosed herein are described using Wi-Fi, however any other wireless technology can be used. Additionally, while there are various methods to conduct Wi-Fi-based localization under different conditions and performance levels (triangulation method, time-of-arrival estimation, etc.), the embodiments disclosed herein will focus on fingerprinting-based approach. In a fingerprinting-based solution, a device that wants to localize itself measures RF signals from various transmitters (denoted as anchors) and inputs those measurements to a trained model that will output a location estimate of the device.
(30) FIG. **1** illustrates an example communication system **100** in accordance with an embodiment of this disclosure. The embodiment of the communication system **100** shown in FIG. **1** is for

illustration only. Other embodiments of the communication system **100** can be used without departing from the scope of this disclosure.
(31) The communication system **100** includes a network **102** that facilitates communication between various components in the communication system **100**. For example, the network **102** can communicate internet protocol (IP) packets, frame relay frames, Asynchronous Transfer Mode (ATM) cells, or other information between network addresses. The network **102** includes one or more local area networks (LANs), metropolitan area networks (MANs), wide area networks (WANs), all or a portion of a global network such as the Internet, or any other communication system or systems at one or more locations.
(32) In this example, the network **102** facilitates communications between a server **104** and various client devices **106-116**. The client devices **106-116** may be, for example, a smartphone, a tablet computer, a laptop, a personal computer, a wearable device, a head mounted display (HMD), or the like. The server **104** can represent one or more servers. Each server **104** includes any suitable computing or processing device that can provide computing services for one or more client devices, such as the client devices **106-116**. Each server **104** could, for example, include one or more processing devices, one or more memories storing instructions and data, and one or more network interfaces facilitating communication over the network **102**.
(33) Each client device **106-116** represents any suitable computing or processing device that interacts with at least one server (such as the server **104**) or other computing device(s) over the network **102**. In this example, the client devices **106-116** include a desktop computer **106**, a mobile telephone or mobile device **108** (such as a smartphone), a PDA **110**, a laptop computer **112**, a tablet computer **114**, and a television **116**. However, any other or additional client devices could be used in the communication system **100**. Smartphones represent a class of mobile devices **108** that are handheld devices with mobile operating systems and integrated mobile broadband cellular network connections for voice, short message service (SMS), and Internet data communications. In certain embodiments, any of the client devices **106-116** can emit and collect signals via a measuring transceiver. For example, any of the client devices **106-116** can emit and collect RF signals.
(34) In this example, some client devices **108-116** communicate indirectly with the network **102**. For example, the mobile device **108** and PDA **110** communicate via one or more base stations **118**, such as cellular base stations or eNodeBs (eNBs). Also, the laptop computer **112** the tablet computer **114**, and the television **116** communicate via one or more wireless access points **120**, such as IEEE 802.11 wireless access points. Note that these are for illustration only and that each client device **106-116** could communicate directly with the network **102** or indirectly with the network **102** via any suitable intermediate device(s) or network(s). In certain embodiments, the server **104** or any client device **106-116** can be used for localizing an electronic device. In certain embodiments, any of the client devices **106-116** transmit information securely and efficiently to another device, such as, for example, the server **104**, the access point **120**, or any other one of the client devices **106-116**.
(35) In certain embodiments, any of the client devices **106-116** or the server **104** can localize another one of the client devices **106-116**. As illustrated, the television **116** can be an immobile device since televisions are not moved on a regular basis. When the television **116** is considered an ‘immobile device,’ which is a device that is moved infrequently, the television **116** is considered an anchor for localizing another one of the client devices **106-114**.
(36) As illustrated, the mobile device **108** can communicate with the laptop computer **112**, the access point **120**, and any other client device. Based on the wireless signals which are communicated between these devices, a localization system coordinator (LSC), which can be the laptop computer **112**, the access point **120**, and any other client device, can identify the location of the mobile device **108** relative to the devices with which it communicates with.
(37) Although FIG. **1** illustrates one example of a communication system **100**, various changes can be made to FIG. **1**. For example, the communication system **100** could include any number of each

component in any suitable arrangement. In general, computing and communication systems come in a wide variety of configurations, and FIG. **1** does not limit the scope of this disclosure to any particular configuration. While FIG. **1** illustrates one operational environment in which various features disclosed in this patent document can be used, these features could be used in any other suitable system.

(38) FIGS. **2** and **3** illustrate example electronic devices in accordance with an embodiment of this disclosure. In particular, FIG. **2** illustrates an example electronic device **200**, and the electronic device **200** could represent the server **104** in FIG. **1**. The electronic device **200** can represent one or more local servers, remote servers, clustered computers, and components that act as a single pool of seamless resources, a cloud-based server, and the like. In certain embodiments, the electronic device **200** can represent an access point, such as the access points **120**. The electronic device can also represent a localization system coordinator (LSC) that coordinates the location services within the environment. The electronic device **200** can be accessed by one or more of the client devices **106-116** of FIG. **1** or another server.

(39) As shown in FIG. **2**, the electronic device **200** includes a bus system **205** that supports communication between at least one processing device (such as a processor **210**), at least one storage device **215**, at least one communication interface **220**, and at least one input/output (I/O) unit **225**.

(40) The processor **210** executes instructions that can be stored in a memory **230**. The processor **210** can include any suitable number(s) and type(s) of processors or other devices in any suitable arrangement. Example types of processors **210** include microprocessors, microcontrollers, digital signal processors, field programmable gate arrays, application specific integrated circuits, and discrete circuitry. In certain embodiments, the processor **210** can generate a localization model based on measurement signals from various anchors within the environment.

(41) The memory **230** and a persistent storage **235** are examples of storage devices **215** that represent any structure(s) capable of storing and facilitating retrieval of information (such as data, program code, or other suitable information on a temporary or permanent basis). The memory **230** can represent a random-access memory or any other suitable volatile or non-volatile storage device(s). For example, the instructions stored in the memory **230** can include instructions for localizing an electronic device within an environment. The persistent storage **235** can contain one or more components or devices supporting longer-term storage of data, such as a read only memory, hard drive, Flash memory, or optical disc.

(42) The communication interface **220** supports communications with other systems or devices. For example, the communication interface **220** could include a network interface card or a wireless transceiver facilitating communications over the network **102** of FIG. **1**. The communication interface **220** can support communications through any suitable physical or wireless communication link(s). For example, the communication interface **220** can transmit a localization map to another device such as one of the client devices **106-116**.

(43) The I/O unit **225** allows for input and output of data. For example, the I/O unit **225** can provide a connection for user input through a keyboard, mouse, keypad, touchscreen, or other suitable input device. The I/O unit **225** can also send output to a display, printer, or other suitable output device. Note, however, that the I/O unit **225** can be omitted, such as when I/O interactions with the electronic device **200** occur via a network connection.

(44) It is noted that the same or similar structure of the electronic device **200** of FIG. **2** could be used in one or more of the various client devices **106-116**. For example, a desktop computer **106** or a laptop computer **112** could have the same or similar structure as that shown in FIG. **2**.

(45) FIG. **3** illustrates an example electronic device **300**, and the electronic device **300** could represent one or more of the client devices **106-116** in FIG. **1**. The electronic device **300** can be a mobile communication device, a desktop computer (similar to the desktop computer **106** of FIG. **1**), a portable electronic device (similar to the mobile device **108**, the PDA **110**, the laptop

computer **112**, or the tablet computer **114** of FIG. **1**), an immobile electronic device (such as an appliance similar to a refrigerator, an oven), and the like. In certain embodiments, one or more of the client devices **106-116** of FIG. **1** can include the same or similar configuration as the electronic device **300**. In certain embodiments, the electronic device **300** is usable with localization.

(46) As shown in FIG. **3**, the electronic device **300** includes an antenna **305**, a radio-frequency (RF) transceiver **310**, transmit (TX) processing circuitry **315**, a microphone **320**, and receive (RX) processing circuitry **325**. The RF transceiver **310** can include, for example, a RF transceiver, a BLUETOOTH transceiver, a WI-FI transceiver, a ZIGBEE transceiver, an infrared transceiver, and various other wireless communication signals. The electronic device **300** also includes a speaker **330**, a processor **340**, an input/output (I/O) interface (IF) **345**, an input **350**, a display **355**, a memory **360**, and a sensor(s) **365**. The memory **360** includes an operating system (OS) **361** and one or more applications **362**.

(47) The RF transceiver **310** can include an antenna array including numerous antennas, such as the antenna **305**. The antennas of the antenna array can include a radiating element composed of a conductive material or a conductive pattern formed in or on a substrate. The transceiver(s) **310** transmit and receive a signal or power to or from the electronic device **300**. For example, the RF transceiver **310** receives, from the antenna **305**, an incoming RF signal transmitted from an access point (such as a base station, WI-FI router, or BLUETOOTH device) or other device of the network **102** (such as a WI-FI, BLUETOOTH, cellular, 5G, LTE, LTE-A, WiMAX, or any other type of wireless network). The RF transceiver **310** down-converts the incoming RF signal to generate an intermediate frequency or baseband signal. The intermediate frequency or baseband signal is sent to the RX processing circuitry **325** that generates a processed baseband signal by filtering, decoding, and/or digitizing the baseband or intermediate frequency signal. The RX processing circuitry **325** transmits the processed baseband signal to the speaker **330** (such as for voice data) or to the processor **340** for further processing (such as for web browsing data).

(48) The TX processing circuitry **315** receives analog or digital voice data from the microphone **320** or other outgoing baseband data from the processor **340**. The outgoing baseband data can include web data, e-mail, or interactive video game data. The TX processing circuitry **315** encodes, multiplexes, and/or digitizes the outgoing baseband data to generate a processed baseband or intermediate frequency signal. The RF transceiver **310** receives the outgoing processed baseband or intermediate frequency signal from the TX processing circuitry **315** and up-converts the baseband or intermediate frequency signal to an RF signal that is transmitted via the antenna **305**.

(49) The processor **340** can include one or more processors or other processing devices. The processor **340** can execute instructions that are stored in the memory **360**, such as the OS **361** in order to control the overall operation of the electronic device **300**. For example, the processor **340** could control the reception of forward channel signals and the transmission of reverse channel signals by the RF transceiver **310**, the RX processing circuitry **325**, and the TX processing circuitry **315** in accordance with well-known principles. The processor **340** can include any suitable number(s) and type(s) of processors or other devices in any suitable arrangement. For example, in certain embodiments, the processor **340** includes at least one microprocessor or microcontroller. Example types of processor **340** include microprocessors, microcontrollers, digital signal processors, field programmable gate arrays, application specific integrated circuits, and discrete circuitry. In certain embodiments, the processor **340** includes a neural network.

(50) The processor **340** is also capable of executing other processes and programs resident in the memory **360**, such as operations that receive and store data. The processor **340** can move data into or out of the memory **360** as required by an executing process. In certain embodiments, the processor **340** is configured to execute the one or more applications **362** based on the OS **361** or in response to signals received from external source(s) or an operator. Example, applications **362** can include localization services, a camera application, a video phone call application, an email client, a social media client, a SMS messaging client, a virtual assistant, and the like.

(51) The processor **340** is also coupled to the I/O interface **345** that provides the electronic device **300** with the ability to connect to other devices, such as client devices **106-116**. The I/O interface **345** is the communication path between these accessories and the processor **340**.
(52) The processor **340** is also coupled to the input **350** and the display **355**. The operator of the electronic device **300** can use the input **350** to enter data or inputs into the electronic device **300**. The input **350** can be a keyboard, touchscreen, mouse, track ball, voice input, or other device capable of acting as a user interface to allow a user to interact with the electronic device **300**. For example, the input **350** can include voice recognition processing, thereby allowing a user to input a voice command. In another example, the input **350** can include a touch panel, a (digital) pen sensor, a key, or an ultrasonic input device. The touch panel can recognize, for example, a touch input in at least one scheme, such as a capacitive scheme, a pressure sensitive scheme, an infrared scheme, or an ultrasonic scheme. The input **350** can be associated with the sensor(s) **365** and/or a camera by providing additional input to the processor **340**. In certain embodiments, the sensor **365** includes one or more inertial measurement units (IMUs) (such as accelerometers, gyroscope, and magnetometer), motion sensors, optical sensors, cameras, pressure sensors, heart rate sensors, altimeter, and the like. The input **350** can also include a control circuit. In the capacitive scheme, the input **350** can recognize touch or proximity.
(53) The display **355** can be a liquid crystal display (LCD), light-emitting diode (LED) display, organic LED (OLED), active matrix OLED (AMOLED), or other display capable of rendering text and/or graphics, such as from websites, videos, games, images, and the like. The display **355** can be sized to fit within an HMD. The display **355** can be a singular display screen or multiple display screens capable of creating a stereoscopic display. In certain embodiments, the display **355** is a heads-up display (HUD).
(54) The memory **360** is coupled to the processor **340**. Part of the memory **360** could include a RAM, and another part of the memory **360** could include a Flash memory or other ROM. The memory **360** can include persistent storage (not shown) that represents any structure(s) capable of storing and facilitating retrieval of information (such as data, program code, and/or other suitable information). The memory **360** can contain one or more components or devices supporting longer-term storage of data, such as a read only memory, hard drive, Flash memory, or optical disc.
(55) The electronic device **300** further includes one or more sensors **365** that can meter a physical quantity or detect an activation state of the electronic device **300** and convert metered or detected information into an electrical signal. For example, the sensor **365** can include one or more buttons for touch input, a camera, a gesture sensor, optical sensors, cameras, one or more inertial measurement units (IMUs), such as a gyroscope or gyro sensor, and an accelerometer. The sensor **265** can also include an air pressure sensor, a magnetic sensor or magnetometer, a grip sensor, a proximity sensor, an ambient light sensor, a bio-physical sensor, a temperature/humidity sensor, an illumination sensor, an Ultraviolet (UV) sensor, an Electromyography (EMG) sensor, an Electroencephalogram (EEG) sensor, an Electrocardiogram (ECG) sensor, an IR sensor, an ultrasound sensor, an iris sensor, a fingerprint sensor, a color sensor (such as a Red Green Blue (RGB) sensor), and the like. The sensor **365** can further include control circuits for controlling any of the sensors included therein. Any of these sensor(s) **365** may be located within the electronic device **300** or within a secondary device operably connected to the electronic device **300**.
(56) Although FIGS. **2** and **3** illustrate examples of electronic devices, various changes can be made to FIGS. **2** and **3**. For example, various components in FIGS. **2** and **3** could be combined, further subdivided, or omitted and additional components could be added according to particular needs. As a particular example, the processor **340** could be divided into multiple processors, such as one or more central processing units (CPUs) and one or more graphics processing units (GPUs). In addition, as with computing and communication, electronic devices and servers can come in a wide variety of configurations, and FIGS. **2** and **3** do not limit this disclosure to any particular electronic device or server.

(57) FIG. **4** illustrates an example architecture of a localization system in accordance with an embodiment of this disclosure. The architecture, as shown in FIG. **4**, describes a Wi-Fi-based localization system. The localization system can be located within a particular environment such as a person's home, place of work, and the like. As indicated above, the localization system can use other wireless communication instead of Wi-Fi. In this embodiment, the learned localization model is generated at one of the anchors as well as the computation to determine the location are performed at one or more of the anchors and not at the electronic device **408** as shown in FIG. **4**.
(58) The architecture of FIG. **4** is for providing a localization service within a particular environment, such as the home of a user. The localization service enables the electronic device **408** to localize itself relative to the other anchors within the network **400**. Here, the anchors for the localizations are taken to be various Wi-Fi-capable devices that are positioned throughout the environment. The Wi-Fi-capable devices include access points (AP) **402***a* and **402***b* (collectively AP **402**), as well as various immobile Wi-Fi devices such as immobile devices **404***a*, **404***b*, and **404**C (collectively immobile device **404**). As shown in FIG. **4**, the trained localization model resides in the collective of the anchors. This means one or more anchors store the trained model and those anchors will response to localization request from the electronic device **408**.
(59) In certain embodiments, one of the anchors (AP **402***a*, AP **402***b*, immobile device **404***a*, immobile device **404***b*, or immobile device **404**C) within the network **400** may act as a Localization Service Coordinator (LSC). The LSC can handle the training data collection, maintenance of the trained model(s), as well as coordination to provide the localization service. In this architecture, one of the anchors (can be an AP or non-AP device) could act as the LSC, which is responsible for coordinating the localization training data collection as well as providing the localization service.
(60) Although FIG. **4** illustrates an example architecture of a localization system, various changes may be made to FIG. **4**. For example, more or less devices, of varying types can be included in the network **400**,
(61) FIG. **5** illustrates a method **500** for a localization system in accordance with an embodiment of this disclosure. The method **500** is described as implemented by any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, or any of the immobile devices **404** of FIG. **4** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the method **500** as shown in FIG. **5** could be used with any other suitable electronic device and in any suitable system.
(62) The method **500** describes that the localization system is separated into three steps denoted as step **510** (also denoted as stage 0), step **520** (also denoted as stage 1), and step **530** (also denoted as stage 2).
(63) During step **510** the LSC selects various devices within the environment and registers the selected devices as anchors. Once the LSC performs selection and setup, the localization system is separated into two stages: the initial data collection stage (stage 1 corresponding to step **520**) and the service operation and maintenance stage (stage 2 corresponding to step **530**). During step **520**, the LSC coordinates and collects training data to train the initial localization model(s). Once the initial localization model(s) are obtained the system is functional and can provide localization service to an electronic device requesting its location within the environment. For example, during step **530** the LSC can provide localization service **532** as well as continue collecting training data in step **534** for maintenance purpose (to be able to get measurements in the latest house environment, which could change over time).
(64) At the very start of the deployment, in step **510**, one of the eligible devices (such as an AP or a non-AP immobile device) is be selected as the LSC. In certain embodiments, the selection is based on a predefined protocol that considers both the device capability (such as computational power and storage) and availability. In certain embodiments, the selection is based on a human operator

with a potentially strategic placement inside the house. For example, the LSC could reach most areas in the house.

(65) Once the LSC is selected, at step **520**, the LSC starts the first stage, which is the initial data collection. At this stage, since there is not enough data to train a localization model yet, the service may not yet be provided. The LSC may start with registering devices before it starts the actual data collection. The data collection is done by requesting cooperation from localization-capable devices. Some of those devices may act as anchors, and some may help in the data collection. For example, only immobile devices (including APs) may act as anchors. Mobile devices such as a smart phone (such as the mobile device **108** of FIG. **1**), fitness band, AR glasses, and the like, may only help in data collection.

(66) In certain embodiments, for devices (such as any of the client devices **106-116** of FIG. **1**) to participate in the localization service (either as anchors or as a consumer/user of the service), there is a registration procedure with the LSC. The registration could be implicit or explicit. In an implicit registration approach, the LSC would broadcast a request for cooperation for localization (could be during the data collection process or when providing localization service to a device; detailed procedures provided later). The LSC would then collect the responses and register the devices that meet the appropriate criteria. If a response belongs to an immobile device, that device could be a potential anchor for the localization, and the LSC could register that device in the list of available anchors. To determine if a device is immobile, the LSC may check the device type of the responder. An example of a concrete list of device types may be something similar to the list defined in the OCF device specification by the Open Connectivity Foundation (OCF). For the user utilizing the localization service, there is no registration required; the user could send a localization request to the LSC and the LSC may response accordingly. Note that in this case there is no explicit authentication step, but only devices connected to the network may participate; the security can be handled by the network authentication implicitly, and only authorized network users can participate in the localization service.

(67) In an explicit registration approach, each device (such as any of the client devices **106-116** of FIG. **1**) can send a registration request to the LSC. The device could be registered as an anchor or as a consumer of the service. The device could indicate its capability (such as whether the device can serve as an anchor) in the registration request. The LSC is responsible for determining whether a device can be an anchor. For example, only immobile devices may be registered as anchors. Before the registration can happen, the LSC may first need to authenticate the requesting device. In this case, during the localization operation (either anchors or user requesting to localize itself), the LSC only accepts responses from devices already registered (and thus authenticated).

(68) Once the devices are registered, FIG. **9**A, below, describes the LSC coordinating training data collection for training localization prediction models. Once the LSC determines it has collected sufficient amount of training data, it can initiate localizations model training to obtain one or more trained localization models. The trained models may be distributed to the participating anchors, or trained models are maintained at the LSC.

(69) After the localization models are trained, at step **530**, the second stage of the operation, which is providing the localization service as well as maintaining the models, is activated. The maintenance operation in step **534** is conducted by the LSC, where it keeps collecting new training data measurements while providing the service. The data collection at this stage can be operated in a sporadic manner. The purpose of the data collection in this stage is to ensure the collected data reflect the current environment, that may change slowly over time.

(70) Although FIG. **5** illustrates an example method, various changes may be made to FIG. **5**. For example, while the method **500** is shown as a series of steps, various steps could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.

(71) FIG. **6** illustrates an example method **600** of a LSC responding to a request for localization in

accordance with an embodiment of this disclosure. FIG. **7**A illustrates an example method **700** of a LSC determining a location of an electronic device in accordance with an embodiment of this disclosure. FIG. **7**B illustrates a timing diagram **750** for localizing an electronic device in accordance with an embodiment of this disclosure. FIG. **8** illustrates a block diagram **800** for partial distributed processing for localization in accordance with an embodiment of this disclosure.

(72) The methods **600** and **700** are described as implemented by any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, or any of the immobile devices **404** of FIG. **4** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the method **600** as shown in FIG. **6** method **700** as shown in FIG. **7**A could be used with any other suitable electronic device and in any suitable system.

(73) In order for an electronic device (such as one of the client devices **106-116** of FIG. **1**) to be able to access the localization service, the electronic device should be aware that the service is available. The availability of the service can be announced in a control message for maintaining the network, provided in a request-response approach, or the like.

(74) The announcement in a control message approach, can notify the electronic device that the network (or system) is capable of providing a localization service. For example, the beacon frames can be used in a Wi-Fi system. One of the reserved field in the network capability information could be used for this purpose. Since all devices have to receive beacons to be able to connect to the network, it would also know whether localization service is available by the time it is connected to the network.

(75) A request-response approach can notify the electronic device that the environment is capable of providing a localization service. The LSC is responsible for responding to such an information request. If the network is an ad hoc network, the device would broadcast its information request, and if the request reaches the LSC or one of the participating anchors, they may respond back with the information. If the network is an infrastructure-based network, the LSC may register with the network (assuming the network supports localization service), and have the network respond to such information request. If an electronic device wants to localize itself, it first sends an information request to obtain the network's capability and checks whether localization service is available. The electronic device may record past responses and save an indication as to whether localization was available for the network. This way, the electronic device does not need to send such information request every time it wants to localize itself.

(76) The method **600**, describes a request-response approach for accessing the localization service. For example, an LSC, which could be one of the anchors, is responsible for responding to localization request from an electronic device (such as any of the client devices **106-116** of FIG. **1**) as well as coordinating the anchors to provide the service. In step **610**, the electronic device transmits a request for localization. In step **620**, one or more of the anchors (such as any other client devices **106-116** of FIG. **1**) receives the request from the electronic device. In certain embodiments, the network could be an ad hoc or an infrastructure-based network. For an ad hoc network, any nodes in the network could receive the request, and in an infrastructure-based network, only the APs may receive the request. Regardless of network type, in step **630**, the anchor(s) that received the request from the electronic device forwards the request to the LSC.

(77) In step **640**, the LSC determines whether the service can be provided. There could be several factors in deciding whether a localization service can be provided. The LSC can check if the electronic device is authorized to use the service if such a policy is adopted. For example, the LSC can verify that the electronic device is authorized via a list of registered devices. Such authentication information could be distributed to the anchors by the LSC. That way, when an anchor receives a localization request, it can check the authentication. If authentication fails, the anchor may choose not to forward the request message to the LSC or the anchor may send a service-reject message (such as the message in step **650**). In certain embodiments, any electronic

device that is connected to the network are allowed to use the localization service, then such authentication is not needed at this stage.
(78) The LSC can also determine whether to provide the localization service based on resource availability. The LSC can check how many anchors are available for providing the localization service. If the number of anchors is lower than some threshold, then localization performance may not be reliable. Therefore, the LSC determines that the localization service cannot be provided.
(79) If the LSC determines that it is not possible to provide the localization service to the electronic device, the LSC, in step **650** would send a service-deny message to the electronic device. Alternatively, if the LSC determines that it is possible to provide the localization service to the electronic device, the LSC, in step **660** would send a service-grant message to the electronic device. Upon determining to grant the localization service, the LSC can then provide the localization service, as described in FIGS. **7**A and **7**B, below.
(80) The response from the LSC (in steps **650** and **660**) could be direct or indirect depending on whether the network allows a direct connection between the LSC and the electronic device. For example, in an ad hoc network, if the LSC can reach the user, it can transmit to the user directly. In an infrastructure-based network, if the LSC is an AP, it can transmit directly, but if it is not, it has to transmit it through an AP. If the localization request is not received by any anchors, there would be no response from an LSC. In that case, the electronic device could resend its request after some timeout period.
(81) In certain embodiments, the LSC can transmit a soft response to the electronic device (not shown). For example, when at least some anchors are available rather than providing a binary response (grant or reject), the LSC may choose to send service grant but indicating that only localization with low accuracy is available, in order to let the electronic device determine whether to proceed with the localization service.
(82) The method **700**, as shown in FIG. **7**A, describes the LSC determining the location of the electronic device within the environment. In certain embodiments, the method **700** is performed after step **660** of FIG. **6**.
(83) In step **702**, the LSC selects a time for performing the RF measurements. The determination can be based on response from the anchors. For example, during the determination of the availability of the anchor(s), as described above, the LSC may obtain information on when those anchors could perform the RF measurements. The LSC could decide a measurement time based on the received information.
(84) Once the LSC decides a measurement time, the LSC in step **704**, notifies both the anchors and the electronic device of that time. This notification can be included in service-grant message of step **660**. For example, the same message can be sent to the anchors and the electronic device. Alternatively, the notification to the anchors may use a different message than the service-grant message (of step **660**) that is sent to the electronic device. In certain embodiments, the LSC assumes the anchors will keep scanning for reception during the time they indicate as available to the LSC, and as such does not send a designated message to the anchors (only the electronic device receives a message with the indicated time).
(85) In step **706**, the electronic device transmits signals for the measurement at the time specified by the LSC (such as in the service-grant message). In step **708**, the anchors would receive and process those signals to some appropriate form. For example, if only the signal strength is used, the signal strength would be estimated; if the estimated channels are used, then the anchors would estimate the channel. In step **710**, the anchors forward the measurements to the LSC. In step **712**, the LSC would proceed to compute the location estimate using those reported measurements. in step **714**, the LSC would send the location estimate to the electronic device.
(86) The timing diagram **750** of FIG. **7**B combines the methods **600** of FIG. **6** and the method **700** of FIG. **7**. That is the timing diagram **750** describes a period of time from the localization request until receipt of the location estimate, based on a case when the localization service is available and

the localization service can be successfully provided (there are enough anchors available for doing RF measurements, and those measurements were obtained without error).

(87) The timing diagram **750** is based on communication between an electronic device **720**, an LSC **730**, and one or more anchors **740**. The electronic device **720** can be any one of the client device **106-116** of FIG. **1** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. The LSC **730** or any of the anchors **740** can be any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, or any of the immobile devices **404** of FIG. **4** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the timing diagram **750** as shown in FIG. **7**B could be used with any other suitable electronic device and in any suitable system.

(88) The electronic device **720** transmits a localization request via message **752**. The localization request can be similar to the localization request of step **610** of FIG. **6**. After the LSC **730** receives the localization request (via message **752**) the LSC **730** transmits a message **754** to the anchors **740**. The message **754**, is to check the availability of the anchors. In certain embodiments, the message **754** represents a single message that is received by any available anchor **740**. In other embodiments, message **754** represents multiple messages. For example, when the message **754** represents multiple messages, the LSC **730** transmits individual messages to each of the anchors **740**. The LSC **730** then receives one or more messages **756** from the anchors **740**.

(89) The LSC **730** transmits the message **758** to the anchors and the message **760** to the electronic device **720**. The message **760**, indicates that the LSC grants the request for localization. The message **760** includes a time that the electronic device **720** is to transmit the message **762** that includes a signal for RF measurements by the anchors **740**.

(90) The message **758**, which the LSC **730** transmits to the anchors **740** represents one of several possibilities. In certain embodiments, the anchors **740** may just listen for the service grant or there could be separate messaging from the LSC **730** to notify the anchors of the scheduled timing for the RF measurements. In certain embodiments, there could be no messages at all for this scheduling info if the anchors **740** can be assumed to keep scanning the channel during the time they indicate they are available.

(91) After the anchors **740** receive the message **762** from the electronic device **720**, the anchors **740**, transmit a message **764** to the LSC **730**. The message **764** includes an RF measurement report that is transmitted by each of the anchors **740** that received the message **762** from the electronic device. The LSC **730** then identifies the location of the electronic device **720** based on (i) the received RF measurement reports included in the messages **764** and (ii) a previously generated localization model. The LSC then transmits a message **766** to the electronic device **720**. The message **766** includes the location of the electronic device **720**.

(92) In certain embodiments, rather than sending the measurements to the LSC **730**, each of the anchors **740** can process the RF measurements to some intermediate form. For example, the trained localization model can be divided into parallel structure that can take RF measurement from each anchor separately. The block diagram **800** of FIG. **8** shows an example of partial distributed processing for localization.

(93) The block diagram **800** shows an example of a model that allows intermediate output calculation to depend only on the measurements from one anchor. This structure allows a partial distributed computation for inference where each of the anchors **740** may process the measurements to the intermediate output and helps reduce the computational burden on the LSC **730**. In this case, each of the anchors **740** would compute the intermediate output using those parallel structure corresponding to its measurement. The anchors **740** then would report those intermediate outputs rather than reporting the RF measurement to the LSC **730**. The LSC **730** would further process those intermediate outputs to get the final location estimate.

(94) Although FIGS. **6**, **7**A, and **7**B illustrates an example methods and timing diagrams, various

changes may be made to FIGS. **6**, **7**A, and **7**B. For example, while the methods **600** and **700** are shown as a series of steps, various steps could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.

(95) FIG. **9**A illustrates an example method **900** of an LSC (such as the LSC **730**) coordinating data collection for generating a localization model in accordance with an embodiment of this disclosure. FIG. **9**B illustrates an example method **910** of associating localization data with implicit labels in accordance with an embodiment of this disclosure. The methods **900** and **910** are described as implemented by any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, or any of the immobile devices **404** of FIG. **4** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the methods **900** and **910** as shown in FIGS. **9**A and **9**B could be used with any other suitable electronic device and in any suitable system.

(96) The LSC **730**, coordinates an automatic collection for training data in order to generate training localization prediction models. This process can include (i) obtaining training data with implicit labels and (ii) obtaining explicit labels. Implicit labels only allow the distinction between locations but the labels by themselves do not have any interpretable meaning. Examples of implicit labels can resemble P1, P2, P3, and the like. In contrast, explicit labels refer to labels with interpretable meanings such as coordinate or some descriptive names (such as living room, kitchen, particular names associated with bedrooms, and the like).

(97) As shown in the method **900**, the automatic data collection process is managed by the LSC **730**. In step **902**, the LSC **730** broadcasts a request for data collection. In step **904**, the LSC **730** receives responses from any devices (these also include immobile devices that might also act as anchors) that are available and could cooperate for data collection. The response from each device can include an indication of its type and its current state. The device type allows the LSC **730** to differentiate mobile devices (such as the mobile device **108**) versus immobile devices. The device state allows the LSC to determine the appropriateness for doing the measurements. A list of device types and their states may be similar to the list defined in the OCF device specification by the OCF. Among these positive responses, the LSC **730** may first check which devices could provide the measurements it needs. Then among those remaining devices, the LSC **730** determines their suitability for the measurement by checking against the device type and state (step **906**). Once the LSC **730** completed the device selection, the LSC **730** would schedule those selected devices for the measurements (step **908**). The LSC **730** would notify the devices on the scheduled measurements as well as coordinating the anchors to do the measurements at those time instants.

(98) For the LSC **730** to determine which measurements to prioritize or to refresh depends on how the training dataset is managed. In certain embodiments, the localization system used an active learning algorithm that may determine what types of data might be more valuable to add to the training dataset.

(99) In certain embodiments, the localization system balances between training dataset by keeping the relative measurements from various device types (such as the mobile devices and immobile devices) and/or labels to be in similar contribution ratios.

(100) In certain embodiments, the localization system sets a goal to keep the most up-to-date training data. For example, if there is a big piece of furniture just brought to the house, it could affect the wireless propagation environment and degrade the localization performance. To account for such environmental variation in the house, the LSC **730** may prioritize to replace training data with old time-stamp while trying to keep a balanced contribution among the different device types or labels as described in the previous approach.

(101) In certain embodiments, a weight function is defined that depends on the time stamp or time difference between the measurement time and the current time. For example, the weight function could be defined such that older samples have smaller weight values than newer samples. The weight function can help the LSC **730** determine which samples in the current training dataset

should be replaced. The LSC **730** may then prioritize the data collection corresponding to those samples with small weights.

(102) Additionally, the LSC **730** can prioritize to replace training data in response to an explicit request from the user.

(103) During the maintenance stage of step **534** of FIG. **5** (such as when the initial localization capability is already enabled), the LSC **730** may request anchors (including itself) to do localization to check if any anchors have been moved. If an anchored is determined to be moved, then training data measured by that anchor are no longer valid. In this case, those training data samples are discarded. Alternatively, the LSC **730** can replace the measurements from that anchor with dummy values. In this situation, once the anchor is determined to be moved, the LSC **730** can increase the frequency to request training data that include that anchor so that the number of samples after being moved to the new location can be restored to a similar level before the displacement. Then, the localization model could be retrained with the new set of training data. This way, the degradation due to a displaced anchor can be mitigated (such as by excluding its data from previous location) and fixed in short duration (due to the action by the LSC **730** to focus on collecting data with this anchor).

(104) Determining if a device is in a state that is suitable for data collection with implicit labels, is based on identifying states with the ability to infer that the electronic device is in some fixed location (although the location itself can be unknown). Here, 'location' is defined with some accuracy level, (such as meter-level accuracy). As discussed above, there are two categories of devices that are considered for data collection, immobile devices and mobile devices.

(105) For data collection with immobile devices, the location of this category of devices are fixed, and thus RF measurements from immobile devices can be collected at any time as long as the device is available for measurement. While the locations of those immobile devices do not change over time, the wireless channel can be affected by the surrounding environment. Therefore, in certain embodiments, multiple samples from each immobile device is collected to account for the different environmental variations. The implicit labels in this case can be obtained directly from the address of those immobile devices. Immobile devices are devices that typically do not move much throughout a particular time period, such as a day, a week, a month, and the like. Example immobile devices include a desktop computer (similar to the desktop computer **106** of FIG. **1**, a TV, appliances (such as an oven, a fridge, an air conditioning unit), and the like.

(106) For data collection with mobile devices, location of this category of devices is not fixed, however certain situations can indicate whether the location is fixed for a period of time. In certain embodiments, the LSC **730** can determine that an electronic device is mobile based on the device type indicated in the step **904**. The LSC **730** can then determine whether the electronic device can be considered stationary based on the indicated state of the device.

(107) For example, one such situation is when the mobile device is charged via a cable to some electrical outlet or some immobile devices (such as the desktop computer **106** of FIG. **1**), and the charging activity can be detected by the mobile device. Since the cable length is limited, it can be inferred that the location of the device is the location of the outlet with the accuracy of the location based on the cable length.

(108) For another example, the device mobility status can also be used to determine the appropriateness for the data collection. Device mobility can be determined from sensors such as Inertial Measurement Unit (IMU) sensors, gyroscope sensors, accelerometer sensors and the like. In this case, the device can be deemed to be appropriate for data collection, when the device remains static for some duration. For instance, the user of the mobile device could place the mobile device on a piece of furniture within the environment (such as a table, a desk, a nightstand, and the like). The user could repeat these placements of the mobile device on the furniture during certain time period on the furniture and thus allow the data collections from these commonly used locations.

(109) The method **910** of FIG. **9**B describes associating localization data with implicit labels. It is noted that the automatic data collection described thus far does not include any labels. Therefore, to include implicit labels with the automatic data collection, in step **912**, the LSC **730** obtains measurements from the mobile devices. in step **914**, the LSC **730** clusters the obtained data. For example, the LSC **730** can apply an unsupervised learning method to cluster the data collected to obtain implicit labels (that can be thought of as corresponding to outlet locations in this case). It is noted that by limiting to fixed but unknown locations as described here, it is possible to collect multiple samples from those locations. The variation comes from the precision of the location (limited by the cable length) as well as the changes in the surrounding environment. When measurements from the mobile device is collected without any restriction, it is not possible to ensure the collection of multiple samples from the same location, which can create difficulty for clustering the data. In step **916**, the LSC **730** pairs the cluster ID (the implicit label) with the corresponding RF measurements to generate the localization training dataset.
(110) Although FIGS. **9**A and **9**B illustrates example methods, various changes may be made to FIGS. **9**A and **9**B. For example, while the methods **900** and **910** are shown as a series of steps, various steps could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.
(111) Depending on applications, implicit labels alone could be enough for the localization. For example, if the location information is used to help enable some location specific services, then there is no need to know absolute locations. In such a case, the user's usage history can be recorded with the implicit location (implicit labels), and the service operation can be customized for each implicit label according to the historical data.
(112) In certain embodiments, absolute location is needed. For example, in some applications, the service customization is not based on historical data but based on some specific use cases. For an in-house use case, it could be to differentiate between the operation in a living room versus operation in a bedroom. FIGS. **10**A and **10**B illustrate example diagrams **1000** and **1010** for mapping implicit labels to explicit labels in accordance with an embodiment of this disclosure.
(113) To broaden the range of location-based applications, explicit labels may also be obtained. Instead of re-collecting training data with explicit labels; the LSC **730** associates existing training data with implicit labels or even the already trained model using implicit labels.
(114) The diagram **1000** of FIG. **10**A describes the LSC **730** associates existing training data with implicit labels. As illustrated in the diagram **1000**, the mapping between implicit and explicit label is used to generate a new training dataset with explicit labels. Since the number of distinct labels could be different, retraining of the model may be needed.
(115) As shown in the diagram **1000**, first the explicit labels are obtained for the various implicit labels. Then, the implicit labels are replaced by the explicit labels to obtain a new training dataset with explicit labels. Note that it is not necessary that the number of implicit labels be the same as the number of explicit labels. The granularity of the explicit labels could be coarser, such as at the room level, while the implicit labels might be collected at meter levels accuracy (multiple locations in the room where there are electrical outlets and where the immobile devices are). Therefore, the retrained model with explicit labels could be different due to the different number of distinct labels.
(116) The diagram **1010** of FIG. **10** B describes the LSC **730** performing an implicit to explicit label mapping on top of the already trained models. The mapping could be application-dependent, so that each application that uses the localization service could interpret the implicit location estimate according to its needs.
(117) As shown in the diagram **1010**, the LSC **730** uses the explicit-to-implicit mapping on the output of the model trained with the implicit labels. Accordingly, there is no additional computation load to retrain the model. Also, one trained model (with implicit labels) could be reused for multiple implicit-to-explicit label mappings that could depend on the applications.
(118) FIG. **11**A illustrates an example method **1100** for requesting explicit labels from a user in

accordance with an embodiment of this disclosure. FIG. **11**B illustrates an example method **1120** for determining explicit location based on sensor data in accordance with an embodiment of this disclosure. The methods **1100** and **1120** are described as implemented by any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, or any of the immobile devices **404** of FIG. **4** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the methods **1100** and **1120** as shown in FIGS. **11**A and **11**B could be used with any other suitable electronic device and in any suitable system.
(119) In certain embodiments, an interface is included on an electronic device for requesting the explicit label from the human user. For example, the LSC **730** can ask the human user for a description associated with each implicit label. The interface could provide the user with a list of standardized location labels such as living room, kitchen, bedroom, entertainment room, and the like. Another option is to allow the human user to provide their own labels. Such customized labels could be helpful when the labels are intended to be used by the human user (such as by a device finding application). This is because the explicit labels provided by a user can provide a better context of the location to the human user. For instance, with a label such as John's bedroom would be easier to understand than a standardized label such as bedroom **2**.
(120) For the procedure to request the explicit labels from the human user, it would depend on whether the explicit label mapping is maintained at the user's device or at the LSC. In cases where some context information on the location (e.g., whether it is a living room or a bedroom) is to be used, it might be beneficial to maintain such a mapping at the LSC side. It is noted that a more specific customization such as where different applications may use different implicit-to-explicit mapping (as described in FIG. **10**B, above) could be beneficial. As such, the mapping (or mappings) might need to be maintained at the user's device side.
(121) The method **1100** of FIG. **11**A describes storing the explicit mapping at the LSC **730**. If the explicit mapping is maintained at the LSC **730**, the LSC **730** would need to request the electronic device **720** (which requested the localization service) to provide the explicit label. In step **1102**, the LSC **730** receives a request for localization from the electronic device **720**. The request for localization can be similar to the request of step **610** of FIG. **6** or the message **752** of FIG. **7**B.
(122) In step **1104**, the LSC **730** processes the request by following the procedure as described above and identifies a localization estimate with implicit labels. In step **1106**, the LSC **730** determines whether an explicit label is needed. If an explicit label is not needed, then the LSC **730**, in step **1108**, transmits the location estimate to the electronic device **720**.
(123) If an explicit label is needed, then the LSC **730**, in step **1110** sends the location estimate (with implicit label) to the electronic device **720** along with a request for an explicit label for that location. To determine if an explicit label is needed, the LSC **730** firsts checks the map it has constructed so far to determine whether the implicit location of the electronic device is mapped to an explicit label. If the location estimate corresponds to a not-yet-mapped implicit label, then the LSC **730** requests the explicit label from the user of the electronic device **720**. The user may or may not respond to the LSC **730** with the explicit label. If the user responds with the explicit label, the LSC **730** incorporates the explicit label into its mapping. This process continues until all the implicit labels are mapped to explicit labels.
(124) Similar to the implicit training data collection, the LSC can keep refreshing the mapping by asking for feedback with a certain periodicity in order to maintain a correct implicit to explicit mapping. For example, if a room changes from John's bedroom to Sally's bedroom, by periodically requesting the feedback the LSC **730** can update the name of the implicit label.
(125) By storing the mapping from implicit to explicit labels on the LSC is beneficial for when the mapping is used by multiple devices. For example, if the explicit label is input by one user, a user on a separate electronic device can obtain the same explicit label without the need to provide the explicit label to the LSC **730**. Additionally since not all electronic devices have a means to provide

an explicit label upon request, by maintaining the mapping between implicit to explicit labels on the LSC **730**, the localization service can provide an explicit label to a device that would otherwise not have the ability to provide the explicit label to the LSC **730**.
(126) In certain embodiments, multiple implicit-to-explicit mapping can be maintained in the memory of the LSC **730**. For example, the LSC **730** can maintain multiple mappings that are tailored to different application classes. In that case, a set of standardized mapping classes may be defined, and the LSC may include the mapping class in the message when requesting explicit labels from the user.
(127) When the LSC **730** stores one or more implicit-to-explicit mappings, it can advertise that capability in a similar manner as advertising the localization service availability as described earlier. Another option is that the LSC may just advertise the localization service availability, and the user may indicate what localization service type it wants (such as implicit or explicit location label). Then, the service grant from the LSC could indicate whether the requested localization type can be fulfilled.
(128) In the case that the implicit-to-explicit mapping is maintained at the electronic device **720**, it may build up the mapping in a similar manner as at the LSC **730** side. When the electronic device **720** receives a new implicit location estimate (from the LSC **730**), the electronic device **720** may check whether that implicit label is already mapped. If not, the electronic device **720** may request the human user to provide an explicit label and use the feedback to create a new entry in the mapping. An advantage for maintaining explicit labels as the electronic device **720** side is that it provides another layer of privacy. The LSC only knows the implicit location labels, while the electronic device **720** can map the implicit location to explicit labels, where the location can be understood and interpreted.
(129) With advanced sensors, in some situations, it could be possible to obtain explicit labels automatically (instead of requesting a manual input from a user for providing the explicit label). In this case, as shown in FIG. **11**B, when receiving a request for explicit labels (step **1122**), the electronic device **720** can try to obtain the sensor data and try to make a determination whether explicit location label can be estimated from the sensor data. If it is possible, in step **1128** the electronic device **720** would estimate the location label using the sensor data and report back with that location estimate as the requested explicit label. If it is determined that it is not possible, then in step **1126**, the electronic device **720** reports that unknown explicit label (or any form to signify that explicit label is not available) and flag that the request for explicit label cannot be fulfilled. The electronic device **720** may also opt to request explicit label from the human user.
(130) One example of such sensor-based location determination maybe the room type determination (such as living room vs kitchen). For instance, in this case whenever the electronic device **720** is requested for an explicit label, it may use its camera to take a photo of the room. The photo may then be input to a machine learning model that determines the room type from the image. The output room type may then be the explicit label. Depending on how the device is being used, taking a picture might not always be possible. For example, if the device is in a low lighting environment or when the device's camera is being blocked, then the photo might be unsuitable for estimating the room type. In such a case, the device may respond back with a message indicting that explicit label is not available, or it may request the human user for the input.
(131) Although FIGS. **11**A and **11**B illustrates example methods, various changes may be made to FIGS. **11**A and **11**B. For example, while the methods **1100** and **1120** are shown as a series of steps, various steps could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.
(132) As described above, the localization model(s) are generated and stored on the LSC **730**. As such, the LSC **730** is responsible for identifying the location estimates of the electronic device **720**. For the LSC **730** to provide the localization of the electronic device **720**, the electronic device **720** transmits a request for localization to the LSC **730**. However, the electronic device **720** can perform

passive localization without requesting localization from the LSC **730**. For example, if the LSC **730** generates the localization model(s) and then transmits the localization model(s) to the electronic device **720**, enables the electronic device **720** to perform the localization without requesting localization from the LSC **730**. The electronic device **720** can request and download the localization model(s) from the LSC **730** once (or whenever the LSC **730** updates the localization model(s)). In the passive mode localization, the electronic device **720** passively scans the channels to try to measure the RF signals transmitted from the various anchors. Once it has enough measurements, it may compute the location estimate locally.

(133) Similarly, the electronic device **720** can still request to perform active localization from the LSC **730** (such as described in step **610** of FIG. **6**). In this case, the electronic device **720** may transmit and the anchors perform the RF measurements, which are collected by the LSC **730**. The LSC **730** then sends the collected measurements to the electronic device **720** for the electronic device **720** to perform the localization.

(134) FIG. **12** illustrates an example method **1200** for generating multiple localization models in accordance with an embodiment of this disclosure. The method **1200** is described as implemented by any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, or any of the immobile devices **404** of FIG. **4** and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the method **1200** as shown in FIG. **12** could be used with any other suitable electronic device and in any suitable system.

(135) After the LSC **730** collected the training data, there are several configurations that the LSC **730** can use to train the localization models depending on the intended operation of the localization service. It is noted that since the data collection depends on the availability of the anchors, there is no guarantee that each collected training sample has measurements from all the anchors. At any given time, only a subset of the anchors may be available to support the data collection based on a request for localization. Several factors can limit the availability of the anchors. One is the coverage of the anchors. For example, in a large environment (such as a big house), an anchor in one corner of the house might have poor propagation channel to the other corner of the house. Therefore, if the mobile device happens to be in such a far corner, likely that anchor cannot measure the RF signals, even if the anchor is available. Another factor is the temporal variation of the resources of the anchors. For instance, depending on the device types, there could be certain times of the day where the anchors are likely more available than other times.

(136) In certain embodiments, the LSC **730** can account for the variation in the number of available anchors **740** for localizing the electronic device **720**. For example, the LSC **730** can account for the variation of the number of anchors in two ways. First, the LSC **730** can train one model that assumes one fixed input dimension (assuming all anchors' measurements are available). In this case, to account for the variations in the set of available anchors, the LSC **730** replaces those missing anchors during the training with dummy data. This is a form of data augmentation. The benefit of this approach is that there is only one model to maintain. However, depending on how large a typical set of available anchors is, the performance might not be very good. For example, when a typical set of available anchors is small compared to all the anchors in the localization system, most of the input becomes dummy input, which makes it hard to achieve good performance. However, in some cases (such as the unavailability due to coverage), the set of unavailable anchors maybe permanent for some part of the coverage area of the localization service. For such a permanent situation, it may be better to train multiple separate models depending on the set of available anchors.

(137) The method **1200** of FIG. **12** describes another approach to deal with unavailable anchors. The method **1200** describes the LSC **730** training multiple models corresponding to different sets of anchors **740**. Regardless of whether the availability of anchors depends on coverage or time, there can be a pattern of when certain anchors are available. As described earlier, the set of available

anchors could depend on the coverage, or it could depend on time. In either case, the set of available anchors would have some identifiable patterns. Therefore, our disclosed solution is to train multiple models for the most commonly observed set of available anchors to squeeze out as much performance as possible.

(138) As illustrated in FIG. **12**. from the overall training data, the LSC **730** identifies K most frequently observed sets of available anchors (step **1202**). It is noted that K is the target number of models. In certain embodiments, K is constrained so as not to be too large (for ease of operation for providing the service and maintenance). In step **1204**, a training dataset is extracted from the overall dataset corresponding to each of the K sets of available anchors. This extraction may not a one-to-one mapping. It could happen that one training sample from the overall dataset might have a set of anchors that is a superset of multiple of the K sets. In that case, that sample can be down sampled to get a sample for each of those multiple sets. Each of the K sets is frequently observed but not always, and thus the trained model needs to handle when not all of the anchors in the set are available. Therefore, training samples in the overall dataset that contains a subset of the target set of anchors should also be included. In step **1206**, the data for each of the K sets are augmented and prepared for training. For example, it may be convenient to have the same input dimension. Thus, similarly as in the case of one model only, the input size can be fixed and such that the measurements of the missing anchors can be replaced by some dummy data. One main purpose for the augmentation is also to deal with this problem of handling the case when not all anchors in the target set are available. If the training data is already rich enough, this augmentation can be omitted. If not, some anchors could be dropped (randomly or following frequently observed patterns in the overall dataset) and their measurements may be replaced with dummy data. In step **1208**, the LSC **730** trains one model for each of the K datasets.

(139) Although FIG. **12** illustrates an example method, various changes may be made to FIG. **12**. For example, while the method **1200** is shown as a series of steps, various steps could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.

(140) FIG. **13** illustrates an example method **1300** for localization by the LSC **730** in accordance with an embodiment of this disclosure. The method **1300** is described as implemented by any one of the client device **106-116** of FIG. **1**, the server **104** of FIG. **1**, the access point **120** of FIG. **1**, any of the access points **402**, any of the immobile devices **404** of FIG. **4**, or the LSC **730** of FIG. **7**B and can include internal components similar to that of electronic device **200** of FIG. **2** and the electronic device **301** of FIG. **3**. However, the method **1300** as shown in FIG. **13** could be used with any other suitable electronic device and in any suitable system.

(141) In step **1302**, the LSC (such as the LSC **730** of FIG. **7**B) obtains a request from an electronic device (such as the electronic device **720** of FIG. **7**B). The request is for localizing the electric device within a given area. The request can be obtained from the electronic device itself or an anchor that received the request from the electronic device and forwarded the request to the LSC. The area includes one or more anchors.

(142) In certain embodiments, the LSC obtains messages from other electronic devices within the area. based on the device type of the other electronic devices the LSC can determine whether the device is an immobile device. Upon determining that the electronic device is an immobile device the LSC can register that device as one of the anchors that are located throughout the environment.

(143) In step **1304**, the LSC transmits a first message to the electronic device (that transmitted the request for localization) and a second message to the one or more anchors within the area. The message that is transmitted to the electronic device includes a time that the electronic device is to transmit a signal. The message that is transmitted to the anchors includes a time that the anchors are to receive the signal from the electronic device. The time included in the message to the electronic device and the time that is included in the message to the anchors can be the same time. The LSC can determine the time based on an indication, from the anchors, that the anchors are available for

localization.
(144) In step **1306**, the LSC receives signal information from the anchors. The signal information is based on the signal that the electronic device transmitted, and the anchors received. In step **1308**, the LSC determines the location of the electronic device based on the received signal information from the anchors. For example, the LSC compares the signal information from the multiple anchors to a localization map (model), which was previously generated by the LSC, to determine the location of the electronic device relative to the various anchors.
(145) To generate the localization map, the LSC obtains messages from other electronic devices. Each message that is received can include a state (or status) of the other electronic device and device type. In response to the LSC determining that the other electronic device is an immobile device, the LSC can receive measurements from that device. In response to the LSC determining that the other electronic device is a mobile device, the LSC determines whether the device state or status matches some predefined criteria. The predefined criteria could specify that the other electronic device is charging or stationary. Upon determining that the other electronic device satisfies the predefined criteria, the LSC can receive measurement information from the other electronic device. The LSC then generates the localization map based on the information from the other electronic devices which are either immobile devices or mobile devices that satisfies the predefined criteria.
(146) In certain embodiments, the LSC can generate multiple localization models based on receiving signals from different sets of anchors. For example, when the LSC receives signal information from a portion of anchors (as compared to all of the anchors in step **1306**), the LSC can select a localization model that was generated based on the same anchors that transmitted the signal information.
(147) In certain embodiments, the localization model can include implicit labels based on measurements received from the anchors. To include the implicit labels in the localization model, the LSC can cluster measurements from one of more of the anchors. In certain embodiments, the localization model can also include explicit labels.
(148) In step **1310**, the LSC transmits the location estimate, based on the localization model and the signals received from the anchors to the electronic device.
(149) FIG. **14** illustrates an example **1400** method for localization by the electronic device **720** in accordance with an embodiment of this disclosure. The method **1400** is described as implemented by any one of the client device **106-116** of FIG. **1**, the electronic device **408** of FIG. **4**, and the electronic device **720** of FIG. **7**B and can include internal components similar to that of the electronic device **301** of FIG. **3**. However, the method **1400** as shown in FIG. **14** could be used with any other suitable electronic device and in any suitable system.
(150) In step **1402**, the electronic device determines whether a localization service is available within an area. In response to determining that the localization service is available within the area, the electronic device transmits to a LSC a request to receive a localization model. The localization model can be generated by the LSC and include implicit labels based on signals that the LSC received from anchors that are positioned throughout the area.
(151) In certain embodiments, to determine whether the localization service is available within the area, the electronic device can transmit an inquiry inquiring as to whether the area supports localization services. After the electronic device transmits the inquiry, the electronic device can receive a response from the LSC indicating that a localization service is available for the electronic device.
(152) In other embodiments, to determine whether the localization service is available within the area, the electronic device can receive an announcement indicating that a localization service is available for the area. For example, upon joining the wireless network for the area, the electronic device can receive the announcement indicating that the localization service is available for the area. The announcement can also include other information associated with the wireless network

and the area.
(153) In step **1404**, the electronic device receives the localization model from the LSC. In step **1406**, the electronic device receives signals from two or more anchors from the anchors that are located throughout the area. The electronic device can then identify measurements from the received signals. In step **1408**, the electronic device identifies its location within the area based on the identified measurements from the anchors and the localization model received from the LSC.
(154) In certain embodiments, to identify its location the electronic device can receive an input indicating an explicit location within the area. The electronic device can map one of the implicit labels included in the localization model to the explicit label.
(155) In certain embodiments, to identify its location the electronic device can capture an image representing a portion of the area. The electronic device can identify a room type based on the image. For example, the electronic device can determine whether the room is a bathroom, a kitchen, a bedroom, and the like, based on the content within the image. The electronic device then assigns an explicit label that corresponds to the room type to the implicit label at the location where the electronic device is located.
(156) Although FIGS. **13** and **14** illustrates example methods, various changes may be made to FIGS. **13** and **14**. For example, while the methods **1300** and **1400** are shown as a series of steps, various steps could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.
(157) The above flowcharts illustrate example methods that can be implemented in accordance with the principles of the present disclosure and various changes could be made to the methods illustrated in the flowcharts herein. For example, while shown as a series of steps, various steps in each figure could overlap, occur in parallel, occur in a different order, or occur multiple times. In another example, steps may be omitted or replaced by other steps.
(158) Although the figures illustrate different examples of user equipment, various changes may be made to the figures. For example, the user equipment can include any number of each component in any suitable arrangement. In general, the figures do not limit the scope of this disclosure to any particular configuration(s). Moreover, while figures illustrate operational environments in which various user equipment features disclosed in this patent document can be used, these features can be used in any other suitable system.
(159) Although the present disclosure has been described with exemplary embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims. None of the description in this application should be read as implying that any particular element, step, or function is an essential element that must be included in the claims scope. The scope of patented subject matter is defined by the claims.

Claims

1. A method for localization, the method comprising: obtaining a request to localize an electronic device within an area, wherein the area includes a set of anchors, wherein the request to localize is transmitted from the electronic device; determining whether to grant or reject the request, including rejecting the request or determining to transmit a first message that indicates the request is granted; transmitting the first message to the electronic device and a second message to the set of anchors based on the determination to grant the request, wherein the first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device; receiving, from the set of anchors, signal information associated with the measurement signal; identifying a location of the electronic device within the area based on the signal information; and transmitting, to the electronic device, the location of the electronic device within the area.

2. The method of claim 1, further comprising: obtaining information from the set of anchors indicating times that the set of anchors are available for localization; and after determining to grant the request, determining the time included in the first and second messages based on the information from the set of anchors, wherein obtaining the request to localize comprises receiving the request to localize forwarded from one or more anchors among the set of anchors that received the request to localize transmitted from the electronic device to a localization coordinating device.
3. The method of claim 1, further comprising obtaining, from a second electronic device, a message indicating a device type of the second electronic device; and in response to determining that the second electronic device is an immobile device, based on the device type, registering the second electronic device as one of the set of anchors.
4. The method of claim 1, further comprising: obtaining, from a second electronic device, a message including a state of the second electronic device and a device type; in response to determining that the second electronic device is a mobile device, based on the device type, determining whether the state of the second electronic device matches one or more predefined criteria; in response to determining that the state of the second electronic device matches the predefined criteria, receiving, from the second electronic device, information representing measurements; and generating a localization model based on the measurements received from the second electronic device and measurement received from the set of anchors that are positioned throughout the area.
5. The method of claim 1, further comprising: generating multiple localization models based on measurement signals received from different subsets of anchors from the set of anchors; receiving the signal information from a portion of the set of anchors; and selecting a first localization model of the multiple localization models corresponding to the signal information received from the portion of the set of anchors that matches one of the different subsets of anchors used to generate the first localization model.
6. The method of claim 1, further comprising: generating a localization model with implicit labels based on measurement received from the set of anchors that are positioned throughout the area; and identifying the location of the electronic device based on the localization model.
7. The method of claim 6, wherein: generating the localization model comprises: transmitting a request for data collection for generating the localization model, receiving responses from multiple electronic devices, the responses from each of the multiple electronic devices include a device state and a device type, generating a schedule for requesting measurements from at least one device of the multiple electronic devices that satisfy one or more predefined criteria based on the device type and the device state, transmitting, to the set of anchors and the at least one device, requests for the measurements according to the schedule, after transmitting the request for the measurements according to the schedule, receiving the measurements from the set of anchors, wherein the measurements are based on signals transmitted from the at least one device to the set of anchors, and generating the localization model based on the measurements received from the set of anchors; and the method further comprises clustering additional measurements from one or more devices to identify the implicit labels.
8. A localization coordinating device comprising: a transceiver; and a processor operably coupled with the transceiver and configured to: obtain a request to localize an electronic device within an area, wherein the area includes a set of anchors, wherein the request to localize is transmitted from the electronic device; determine whether to grant or reject the request, wherein to determine whether to grant or reject the request, the processor is configured to reject the request or to determine to transmit a first message that indicates the request is granted; transmit the first message to the electronic device and a second message to the set of anchors based on the determination to grant the request, wherein the first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device; receive, from the set of anchors, signal information

associated with the measurement signal; identify a location of the electronic device within the area based on the signal information; and transmit, to the electronic device, the location of the electronic device within the area.

9. The localization coordinating device of claim 8, wherein the processor is further configured to: obtain information from the set of anchors indicating times that the set of anchors are available for localization; and after the determination to grant the request, determine the time included in the first and second messages based on the information from the set of anchors, wherein the request to localize transmitted from the electronic device is received by one or more anchors among the set of anchors, and forwarded to the localization coordinating device by the one or more anchors that received the request to localize the electronic device.

10. The localization coordinating device of claim 8, wherein the processor is further configured to obtain, from a second electronic device, a message indicating a device type of the second electronic device; and in response to determining that the second electronic device is an immobile device, based on the device type, register the second electronic device as one of the set of anchors.

11. The localization coordinating device of claim 8, wherein the processor is further configured to: obtain, from a second electronic device, a message including a state of the second electronic device and a device type; in response to determining that the second electronic device is a mobile device, based on the device type, determine whether the state of the second electronic device matches one or more predefined criteria; in response to determining that the state of the second electronic device matches the predefined criteria, receive, from the second electronic device, information representing measurements; and generate a localization model based on the measurements received from the second electronic device and measurement received from the set of anchors that are positioned throughout the area.

12. The localization coordinating device of claim 8, wherein the processor is further configured to: generate multiple localization models based on measurement signals received from different subsets of anchors from the set of anchors; receive the signal information from a portion of the set of anchors; and select a first localization model of the multiple localization models corresponding to the signal information received from the portion of the set of anchors that matches one of the different subsets of anchors used to generate the first localization model.

13. The localization coordinating device of claim 8, wherein the processor is further configured to: generate a localization model with implicit labels based on measurement received from the set of anchors that are positioned throughout the area; and identify the location of the electronic device based on the localization model.

14. The localization coordinating device of claim 13, wherein: to generate the localization model, the processor is configured to: transmit a request for data collection for generating the localization model, receive responses from multiple electronic devices, the responses from each of the multiple electronic devices include a device state and a device type, generate a schedule for requesting measurements from at least one device of the multiple electronic devices that satisfy a predefined criteria based on the device type and the device state, transmit, to the set of anchors and the at least one device, requests for the measurements according to the schedule, after transmitting the request for the measurements according to the schedule, receive the measurements from the set of anchors, wherein the measurements are based on signals transmitted from the at least one device to the set of anchors, and generate the localization model based on the measurements received from the set of anchors; and the processor is further configured to cluster additional measurements from one or more devices to identify the implicit labels.

15. A non-transitory computer readable medium embodying a computer program, the computer program comprising computer readable program code that, when executed by a processor of a localization coordinating device, causes the processor to: obtain a request to localize an electronic device within an area, wherein the area includes a set of anchors, wherein the request to localize is transmitted from the electronic device; determine whether to grant or reject the request, wherein to

determine whether to grant or reject the request, the processor is configured to reject the request or to determine to transmit a first message that indicates the request is granted; transmit the first message to the electronic device and a second message to the set of anchors based on the determination to grant the request, wherein the first message includes a time for the electronic device to transmit a measurement signal and the second message includes the time for the set of anchors to receive the measurement signal from the electronic device; receive, from the set of anchors, signal information associated with the measurement signal; identify a location of the electronic device within the area based on the signal information; and transmit, to the electronic device, the location of the electronic device within the area.

16. The non-transitory computer readable medium of claim 15, wherein the computer readable program code, when executed by the processor, further causes the processor to: obtain information from the set of anchors indicating times that the set of anchors are available for localization; and after the determination to grant the request, determine the time included in the first and second messages based on the information from the set of anchors, wherein obtaining the request to localize comprises receiving the request to localize forwarded from one or more anchors among the set of anchors that received the request to localize transmitted from the electronic device to a localization coordinating device.

17. The non-transitory computer readable medium of claim 15, wherein the computer readable program code, when executed by the processor, further causes the processor to: obtain, from a second electronic device, a message indicating a device type of the second electronic device; and in response to determining that the second electronic device is an immobile device, based on the device type, register the second electronic device as one of the set of anchors.

18. The non-transitory computer readable medium of claim 15, wherein the computer readable program code, when executed by the processor, further causes the processor to: obtain, from a second electronic device, a message including a state of the second electronic device and a device type; in response to determining that the second electronic device is a mobile device, based on the device type, determine whether the state of the second electronic device matches a predefined criteria; in response to determining that the state of the second electronic device matches the predefined criteria, receive, from the second electronic device, information representing measurements; and generate a localization model based on the measurements received from the second electronic device and measurement received from the set of anchors that are positioned throughout the area.

19. The non-transitory computer readable medium of claim 15, wherein the computer readable program code, when executed by the processor, further causes the processor to: generate a localization model with implicit labels based on measurement received from the set of anchors that are positioned throughout the area; and identify the location of the electronic device based on the localization model.

20. The non-transitory computer readable medium of claim 19, wherein: to generate the localization model, the computer readable program code, when executed by the processor, further causes the processor to: transmit a request for data collection for generating the localization model, receive responses from multiple electronic devices, the responses from each of the multiple electronic devices include a device state and a device type, generate a schedule for requesting measurements from at least one device of the multiple electronic devices that satisfy a predefined criteria based on the device type and the device state, transmit, to the set of anchors and the at least one device, requests for the measurements according to the schedule, after transmitting the request for the measurements according to the schedule, receive the measurements from the set of anchors, wherein the measurements are based on signals transmitted from the at least one device to the set of anchors, and generate the localization model based on the measurements received from the set of anchors; and the computer readable program code, when executed by the processor, further causes

the processor to cluster additional measurements from one or more devices to identify the implicit labels.