US011307286B1

(12) United States Patent
Wang et al.

(10) Patent No.: US 11,307,286 B1
(45) Date of Patent: Apr. 19, 2022

(54) WIRELESS FINGERPRINT RECONSTRUCTION FOR ACCURATE LOCATION CONFIRMATION

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/900,004**

(22) Filed: **Jun. 12, 2020**

(51) **Int. Cl.**
G01S 5/02 (2010.01)
G06Q 10/08 (2012.01)
G06N 20/00 (2019.01)

(52) **U.S. Cl.**
CPC ***G01S 5/02527*** (2020.05); ***G06N 20/00*** (2019.01); ***G06Q 10/083*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 64/00; H04W 4/02; G01S 5/02527; G06N 20/00; G06Q 10/083
See application file for complete search history.

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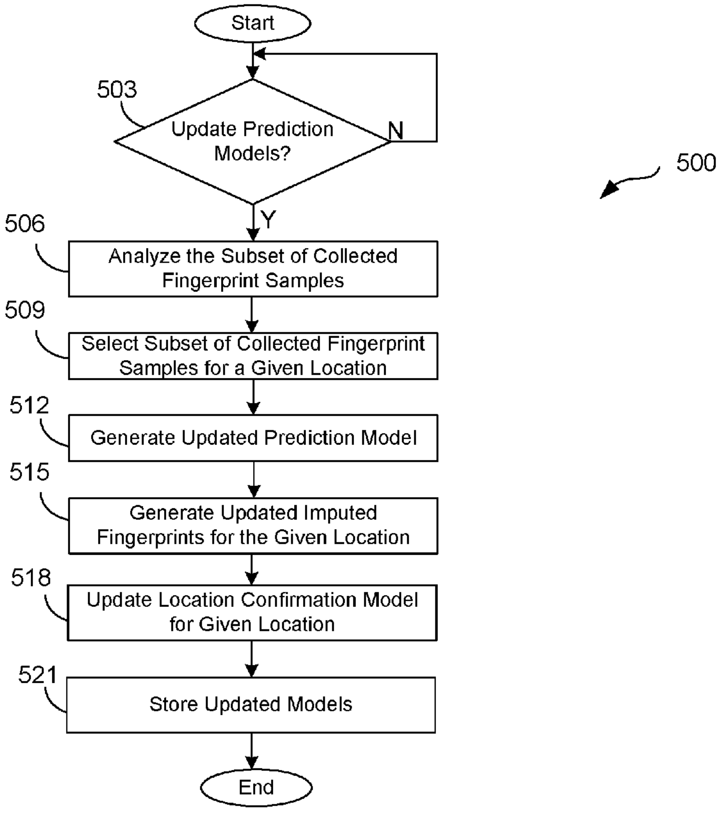
(57) **ABSTRACT**

Disclosed are various embodiments for estimating missing wireless attributes of a wireless fingerprint generated for a given location and confirming that the given location is a correct location. A collection of wireless fingerprint samples for the given location can be used to train an attribute prediction model that can estimate missing attributes in wireless fingerprints. For example, a wireless fingerprint may be incomplete as the fingerprint may fail to include attribute data for some AP devices associated with the given location. The attribute prediction model can be used to reconstruct wireless fingerprints to include the missing attributes. The reconstructed wireless fingerprints can then be used to train a location confirmation model which can be used for accurate location confirmation.

20 Claims, 6 Drawing Sheets


Start
503
Update Prediction Models?
N
Y
506
Analyze the Subset of Collected Fingerprint Samples
509
Select Subset of Collected Fingerprint Samples for a Given Location
512
Generate Updated Prediction Model
515
Generate Updated Imputed Fingerprints for the Given Location
518
Update Location Confirmation Model for Given Location
521
Store Updated Models
End
500

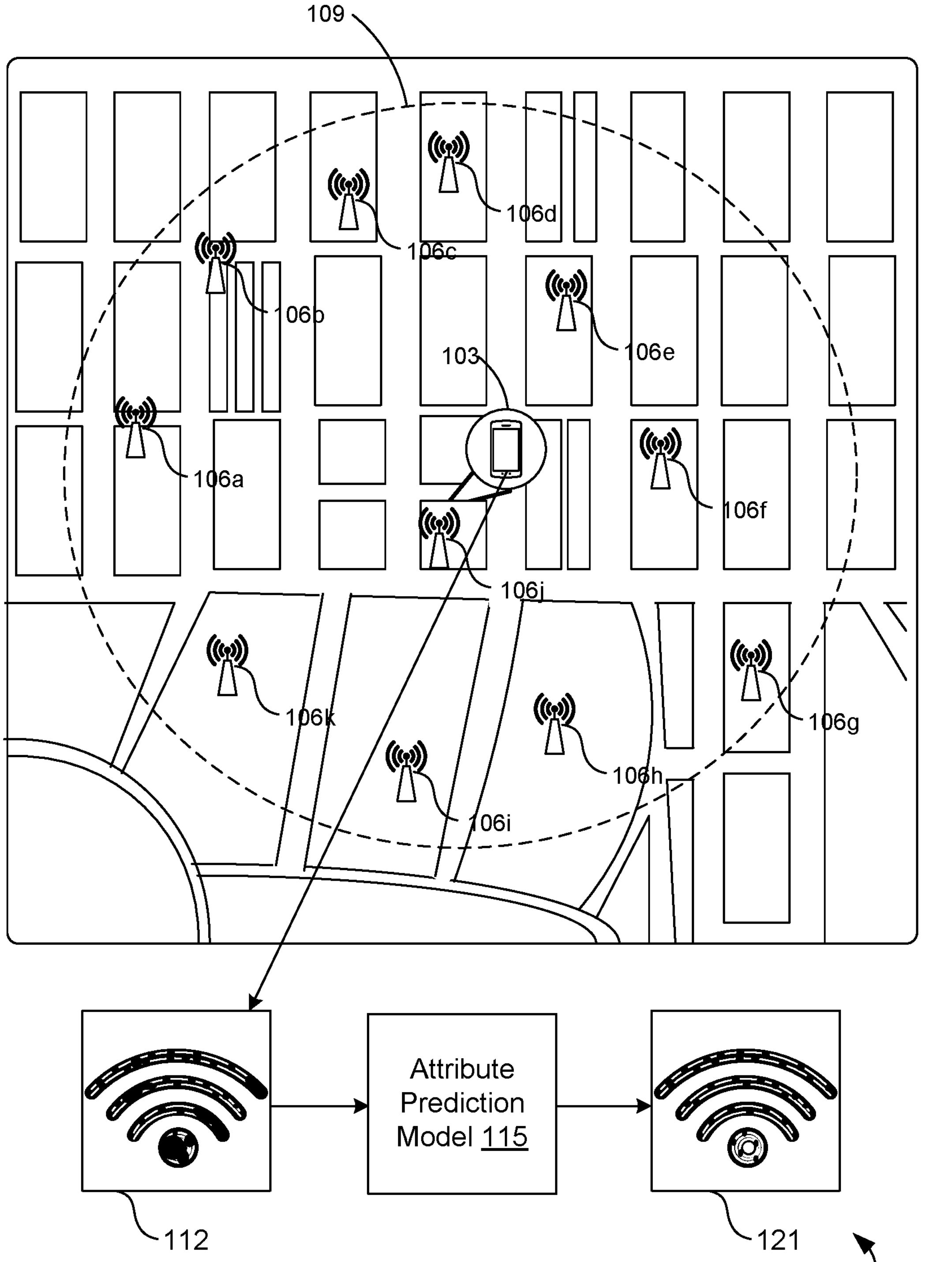

109
106d
106c
106b
106e
103
106a
106f
106j
106k
106g
106h
106i
Attribute Prediction Model 115
112
121
100

FIG. 1

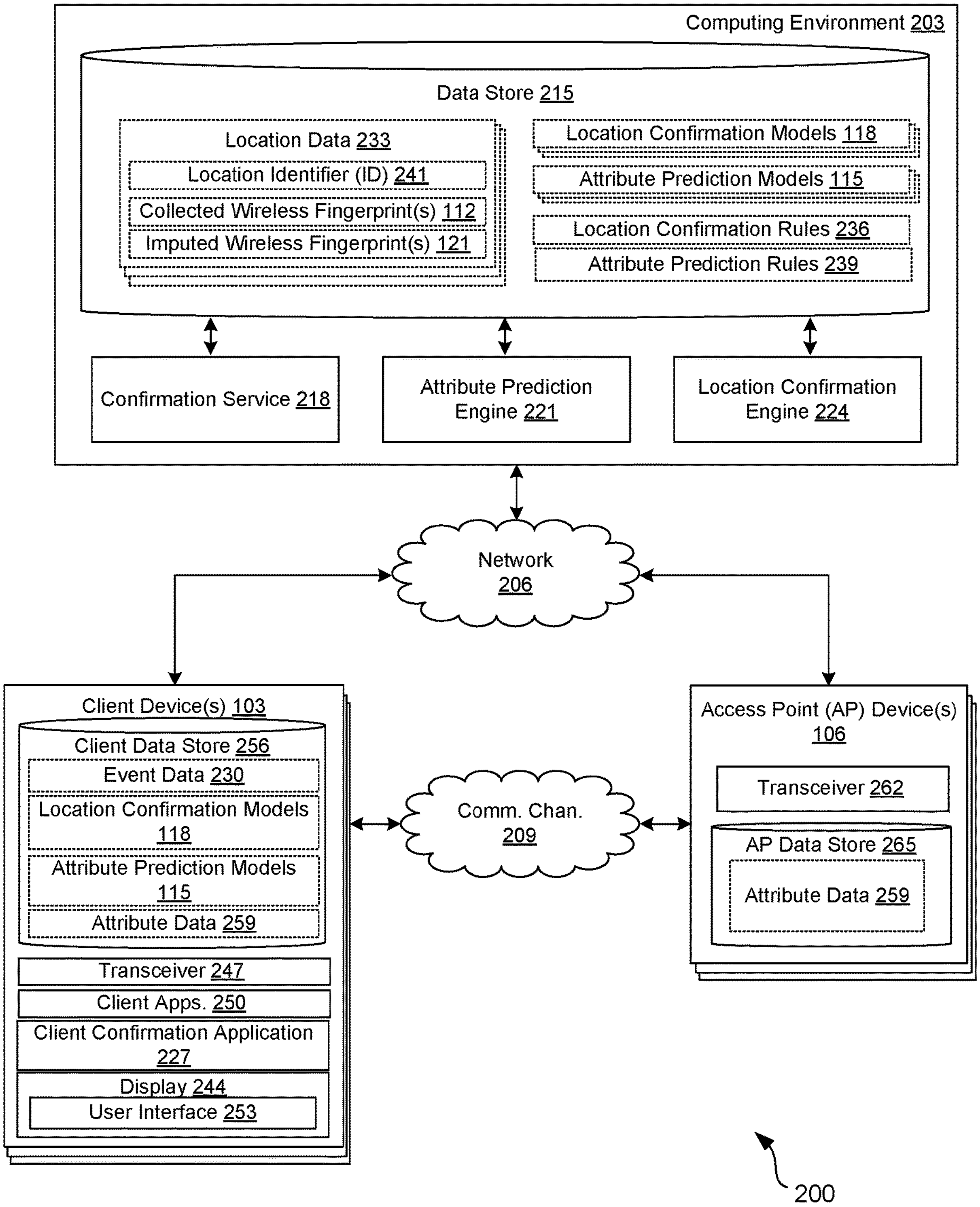

Computing Environment 203
Data Store 215
Location Data 233
Location Identifier (ID) 241
Collected Wireless Fingerprint(s) 112
Imputed Wireless Fingerprint(s) 121
Location Confirmation Models 118
Attribute Prediction Models 115
Location Confirmation Rules 236
Attribute Prediction Rules 239
Confirmation Service 218
Attribute Prediction Engine 221
Location Confirmation Engine 224
Network 206
Client Device(s) 103
Client Data Store 256
Event Data 230
Location Confirmation Models 118
Attribute Prediction Models 115
Attribute Data 259
Transceiver 247
Client Apps. 250
Client Confirmation Application 227
Display 244
User Interface 253
Comm. Chan. 209
Access Point (AP) Device(s) 106
Transceiver 262
AP Data Store 265
Attribute Data 259
200

FIG. 2

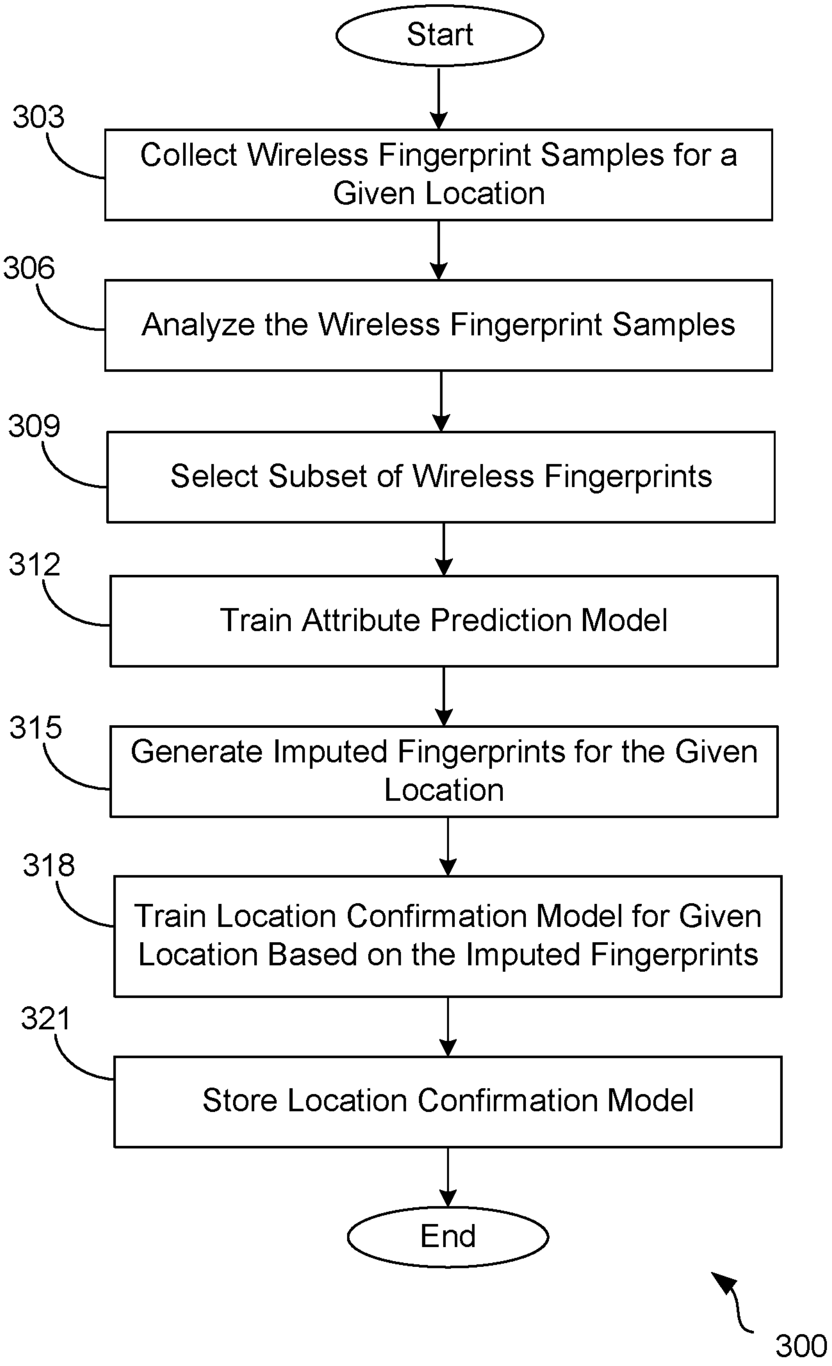

Start
303
Collect Wireless Fingerprint Samples for a Given Location
306
Analyze the Wireless Fingerprint Samples
309
Select Subset of Wireless Fingerprints
312
Train Attribute Prediction Model
315
Generate Imputed Fingerprints for the Given Location
318
Train Location Confirmation Model for Given Location Based on the Imputed Fingerprints
321
Store Location Confirmation Model
End
300

FIG. 3

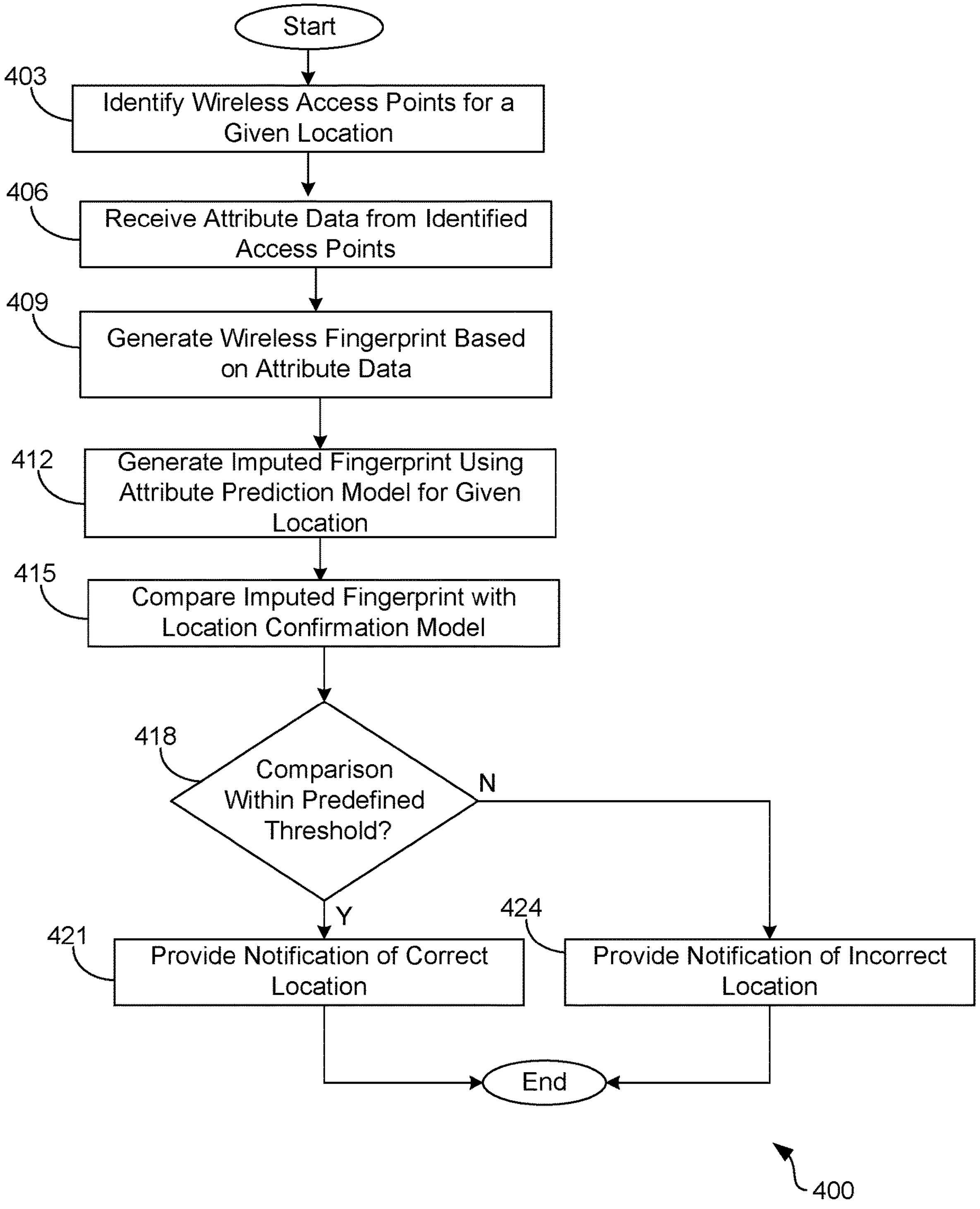

Start
403
Identify Wireless Access Points for a Given Location
406
Receive Attribute Data from Identified Access Points
409
Generate Wireless Fingerprint Based on Attribute Data
412
Generate Imputed Fingerprint Using Attribute Prediction Model for Given Location
415
Compare Imputed Fingerprint with Location Confirmation Model
418
Comparison Within Predefined Threshold?
N
Y
421
Provide Notification of Correct Location
424
Provide Notification of Incorrect Location
End
400

FIG. 4

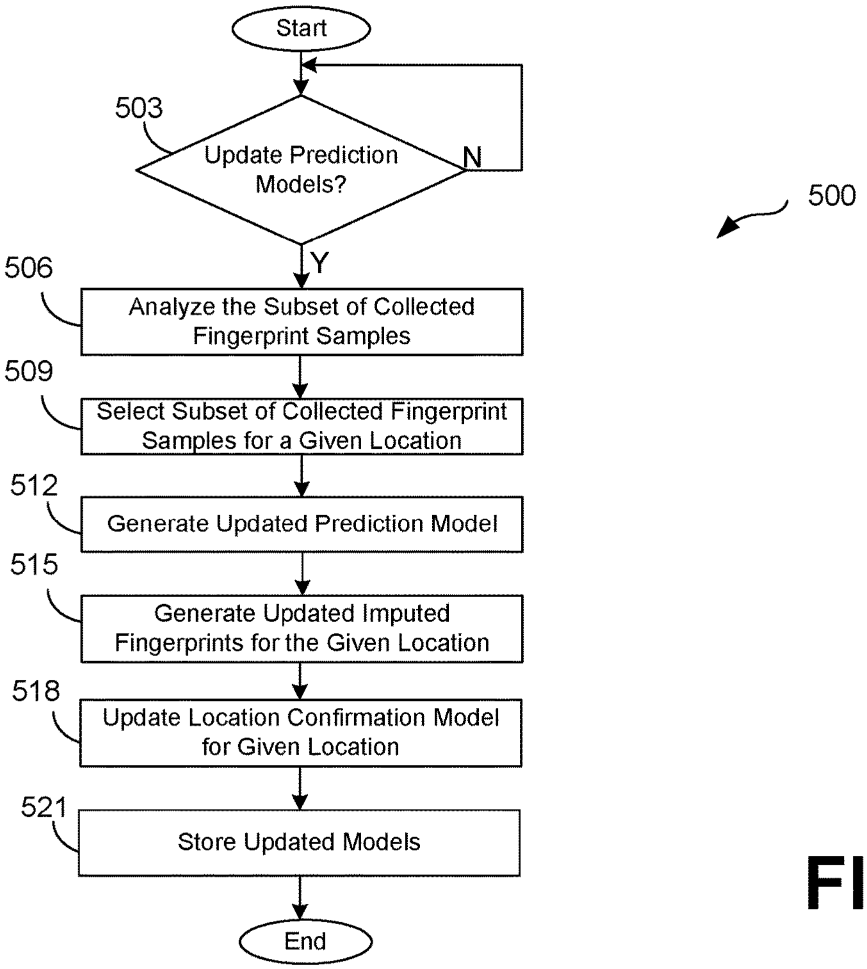
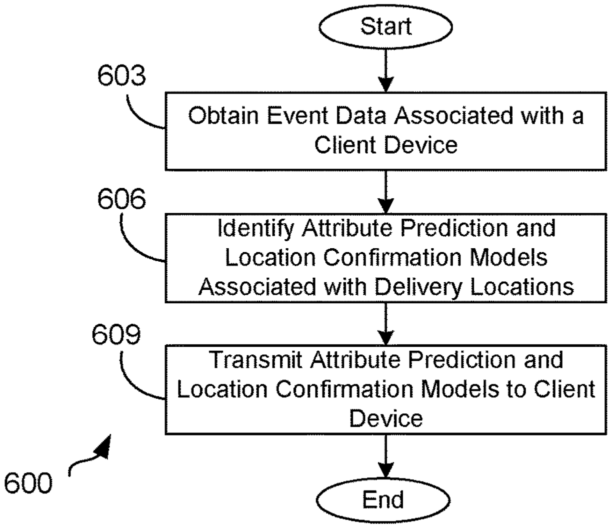

Start
503
Update Prediction Models?
N
Y
500
506
Analyze the Subset of Collected Fingerprint Samples
509
Select Subset of Collected Fingerprint Samples for a Given Location
512
Generate Updated Prediction Model
515
Generate Updated Imputed Fingerprints for the Given Location
518
Update Location Confirmation Model for Given Location
521
Store Updated Models
End

FIG. 5

FIG. 6


Start
603
Obtain Event Data Associated with a Client Device
606
Identify Attribute Prediction and Location Confirmation Models Associated with Delivery Locations
609
Transmit Attribute Prediction and Location Confirmation Models to Client Device
600
End

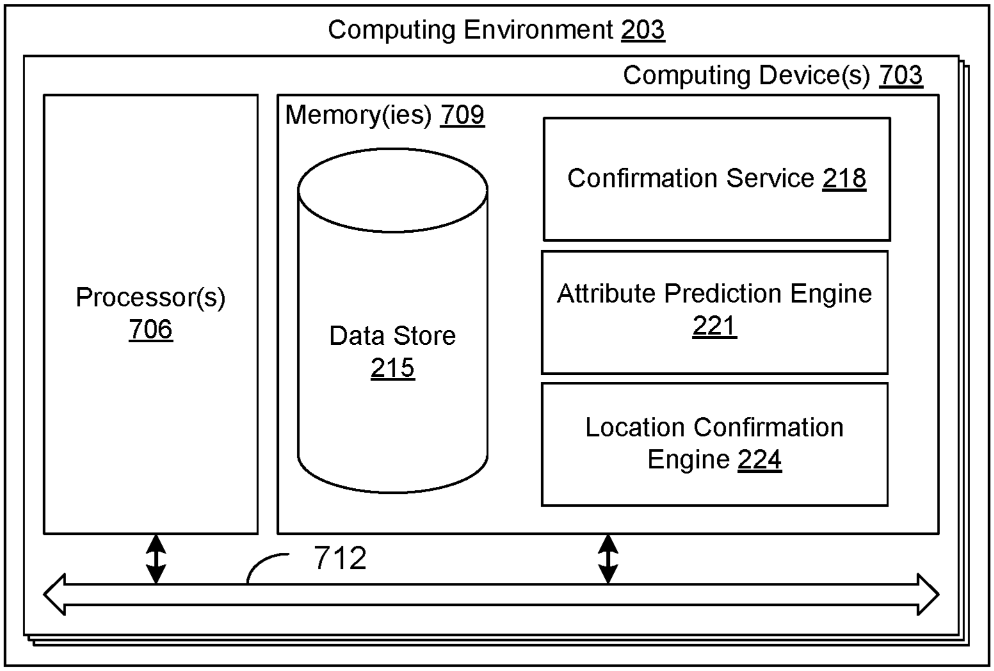

Computing Environment 203
Computing Device(s) 703
Processor(s) 706
Memory(ies) 709
Data Store 215
Confirmation Service 218
Attribute Prediction Engine 221
Location Confirmation Engine 224
712

FIG. 7

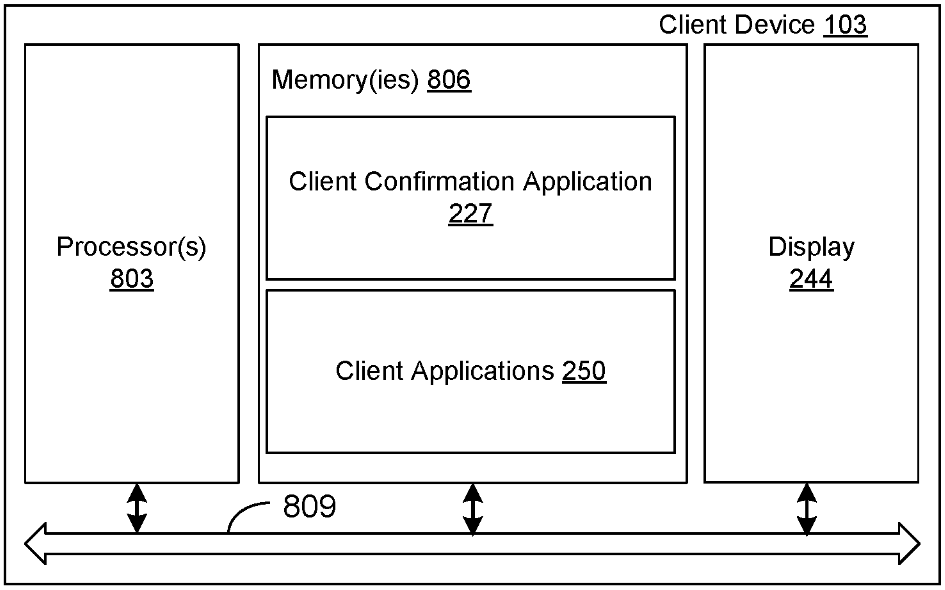

Client Device 103
Processor(s) 803
Memory(ies) 806
Client Confirmation Application 227
Client Applications 250
Display 244
809

FIG. 8

WIRELESS FINGERPRINT RECONSTRUCTION FOR ACCURATE LOCATION CONFIRMATION

BACKGROUND

In a product fulfillment context, delivery confirmation involves ensuring that ordered items are delivered to the appropriate recipients at their specified delivery location. Lacking an accurate delivery confirmation can cause not only customer frustration (e.g., a customer reports that an item is not received) but also driver frustration (e.g., when a driver is unable to locate a particular location). Delivery agents can use global positioning system (GPS) devices to provide a route to a delivery address provided by the intended recipient. Even with GPS systems, delivery agents can have difficulty identifying the appropriate physical location of the delivery address.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a drawing of an example scenario related to wireless localization according to various embodiments of the present disclosure.

FIG. **2** is a schematic block diagram of a networked environment according to various embodiments of the present disclosure.

FIG. **3** is a flowchart illustrating one example of functionality implemented as portions of a confirmation service, an attribute prediction engine, and a location confirmation engine executed in a computing environment in the networked environment of FIG. **2** according to various embodiments of the present disclosure.

FIG. **4** is a flowchart illustrating one example of functionality implemented as a portion of a client confirmation service executed in a client device in the networked environment of FIG. **2** according to various embodiments of the present disclosure.

FIG. **5** is a flowchart illustrating one example of functionality implemented as portions of the confirmation service, the attribute prediction engine, and the location confirmation engine executed in a computing environment in the networked environment of FIG. **2** according to various embodiments of the present disclosure.

FIG. **6** is a flowchart illustrating one example of functionality implemented as portions of the confirmation service executed in a computing environment in the networked environment of FIG. **2** according to various embodiments of the present disclosure.

FIG. **7** is a schematic block diagram that provides one example illustration of a computing environment employed in the networked environment of FIG. **2** according to various embodiments of the present disclosure.

FIG. **8** is a schematic block diagram that provides one example illustration of a client device employed in the networked environment of FIG. **2** according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

The present disclosure relates to estimating missing wireless attributes of a wireless fingerprint generated for a given location and confirming that the given location is a correct location (e.g., delivery address) using an imputed wireless fingerprint that includes the estimated missing wireless attributes. In particular, the computing device can perform a passive or active wireless scan of a given network (e.g., a wireless fidelity (Wi-Fi) network, a Bluetooth network, a Zigbee network, a Near Field Communication (NFC) network, etc.) to identify access point (AP) devices surrounding a given location. A wireless fingerprint corresponds to a unique signature for a given location according to attributes of surrounding AP devices. As such, a wireless fingerprint may be generated using attribute data (e.g., signal strength, distance between devices, etc.) received from or otherwise associated with the identified AP devices.

However, the wireless fingerprint can be incomplete by failing to include attribute data for all of the AP devices associated with the given location. According to various embodiments, multiple fingerprint samples obtained at the given location can be used to generate an attribute prediction model that can be used to estimate missing attributes for a given wireless fingerprint. Accordingly, an imputed or otherwise reconstructed wireless fingerprint that includes the estimated missing attributes from an obtained wireless fingerprint can be used for accurate wireless localization.

Typically, location confirmation, as well as all wireless localization techniques, include two phases: the survey phase and the online confirmation phase. In the survey phase, wireless fingerprints are collected from various locations and a machine learning algorithm is applied to generate a fingerprint model for a given location. For example, the surveyed wireless fingerprints may be collected silently from past successful deliveries for each delivery location. In this example, when a delivery agent delivers an item, the delivery agent can interact with a delivery application to confirm that an item was delivered. In response, the delivery application may identify AP devices in the surrounding area to generate a wireless fingerprint that can be used during the survey phase. Various approaches for collecting wireless fingerprints are described in U.S. patent application Ser. No. 16/900,057 entitled "LOCATION CONFIRMATION USING CROWDSOURCED WIRELESS FINGERPRINTS," filed Jun. 12, 2020, which is incorporated by reference herein in its entirety.

In the online confirmation phase, a wireless fingerprint is collected from a wireless scan when the transporter (e.g., scanning delivery device) arrives at the delivery destination. The transporter's real-time wireless fingerprint is compared against the fingerprint model or location confirmation model for the target delivery location. The comparison result can be used to confirm if the destination location of the transporter is the targeted delivery location.

However, wireless fingerprinting can be highly dimensional as there are multiple types of attributes that make up a wireless fingerprint. In addition, wireless scanning can be opportunistic. For each location, the amount of surrounding access point (AP) devices (e.g., wireless APs) can be different resulting in variational dimensionality in wireless fingerprints. Due to the design and implementation (e.g., hardware and software) of wireless scanning, wireless scanning cannot guarantee retrieving signal attributes from all surrounding AP devices. Thus, a wireless fingerprint will likely only contain a subset of the surrounding network devices.

Using Wi-Fi passive scanning as an example, the scanning device may hop over frequency channels and stay in each channel for a short period of time (e.g., 100 milliseconds) to detect potential access point probe frames. There are eleven channels in the Wi-Fi 2.4 GHz spectrum. From each received probe frame, the signal attributes, including the basic service set identifier (BSSID), the service set identifier (SSID), and the received signal strength indicator (RSSI), etc., are extracted. However, channel hopping can make Wi-Fi scanning unreliable. For example, a probe frame may not be sent timely. Further, should the probe frame be sent, the scanning device may not receive the probe frame due to environment noises or other factors. Furthermore, current industry standards for wireless scanning do not require AP devices to provide information to requesting scanning devices.

The unseen access points (e.g., the missing values or attributes of a wireless fingerprint) can cause challenges to both the survey and the online confirmation phases. In the survey phase, the missing values will decrease the accuracy in model parameters estimation (e.g., the mean and variance of an AP device). Furthermore, many machine learning (ML) algorithms require a fixed size input and missing values will exclude these families of ML algorithms. To compensate, more training samples are required for accurate parameter estimation. Modifications are required for ML algorithms to take variable size input. Such modifications will introduce extra parameters as well as potential degradations to the algorithms. In the online confirmation phase, the accuracy of distance metrics used for comparison may suffer from missing values in fingerprints.

According to various embodiments of the present disclosure, signal attributes can be estimated from unseen AP devices (e.g., the missing values of a wireless fingerprint). An objective of the present disclosure is to impute (or reconstruct) the missing signal attributes as close as possible to the actual signal attributes, should they have been seen. By being able to modify an obtained wireless fingerprint to include missing attributes of unseen AP devices, the accuracy of wireless localization technologies can be improved. Although the discussion in the present disclosure refers primarily to Wi-Fi networks, it should be noted that the examples of the present disclosure can be used with all wireless protocols including, for example, Wi-Fi®, Bluetooth®, Near Field Communication (NFC), Zigbee®, Z-Wave®, 6LoWPAN, Radio Frequency Identification (RFID), cellular 4G network, cellular 5G network, and other wireless protocols.

Turning now to FIG. **1**, shown is an example scenario **100** associated with a delivery agent making a delivery at a given location and using the embodiments of the present disclosure for accurate delivery confirmation. For example, a delivery agent can interact with a client device **103** when delivering an item at a given location to confirm accuracy of the given location. FIG. **1** shows multiple wireless AP devices **106** (e.g., **106***a*, **106***b*, **106***c*, **106***d*, **106***e*, **106***f*, **106***g*, **106***h*, **106***i*, **106***j*, and **106***k*) positioned in various locations within a surrounding area **109** of the location of the client device **103**. The example scenario of FIG. **1** can be used to illustrate both the survey phase and the online confirmation phase associated with wireless localization techniques (e.g., location confirmation).

In the survey phase, each time a delivery agent delivers an item at a given location, the client device **103** can perform a wireless scan to identify wireless AP devices **106** in the surrounding area **109** and generate a collected wireless fingerprint **112** using the attributes received from each of the collected wireless AP devices **106**. Due to hardware and software limitations in wireless scanning, the client device **103** may identify only a subset of the available wireless AP devices **106** in the surrounding area **109**. As such, the collected wireless fingerprint **112** generated according to the scan may be incomplete. In addition, every time a wireless scan is performed at the given location, the generated collected wireless fingerprint **112** may differ from a previously generated collected wireless fingerprint **112** since the client device **103** may identify a different subset of wireless AP devices **106**.

The samples of the collected wireless fingerprints **112** collected over a period of time can be used to generate an attribute prediction model **115**. Typically, in the survey phase, the samples of collected wireless fingerprints **112** are used to generate location confirmation models **118** (FIG. **2**) (e.g., fingerprint models) that can be used for location confirmation based on wireless fingerprinting techniques. However, according to various embodiments, the collected samples are first used to train or otherwise generate an attribute prediction model **115** for the given location. The attribute prediction model **115** can be trained to estimate missing attributes for a given obtained collected wireless fingerprint **112**. Upon training of the attribute prediction model **115**, imputed wireless fingerprints **121** can be generated according to the samples of the collected wireless fingerprints **112** and the attribute prediction model **115**. The imputed wireless fingerprints **121** can then be used to generate location confirmation models **118** for the given location. Because the imputed wireless fingerprints **121** are generated to included estimated missing data, the imputed wireless fingerprints **121** can be considered to be more robust in training an accurate location confirmation model **118** that more accurately reflects the wireless AP environment for the given location.

The online confirmation phase corresponds to the use of the trained location confirmation models **118** to confirm that a particular location is the correct location. Using the example of FIG. **1**, a delivery agent can interact with his or her client device **103** to confirm whether a present location is the accurate delivery location for a delivery of an item. The client device **103** can perform a wireless scan to identify wireless AP devices **106** in the given area. The client device **103** can obtain and/or determine attribute data (e.g., signal strength, device identifier, location of given wireless AP device **106**, a distance between the client device **103** and a given wireless AP device **106**, etc.) from the identified AP devices **106** and generate a collected wireless fingerprint **112** for the given location.

However, as the scan may only include a subset of wireless AP devices **106** in the surrounding area **109**, the collected wireless fingerprint **112** may be incomplete. As such, the client device **103** can apply a previously trained attribute prediction model **115** for the given location to estimate the missing attributes needed to generate an imputed wireless fingerprint **121** that is more complete. Upon generating the imputed wireless fingerprint **121**, the client device **103** can compare a previously generated location confirmation model **118** with the generated imputed wireless fingerprint **121** to confirm a delivery location. If the imputed wireless fingerprint **121** is within a threshold of expectation defined by the location confirmation model **118**, the delivery location can be confirmed as being accurate. Otherwise, the delivery agent may receive a notification rendered on the client device **103** indicating that the delivery location is incorrect. In the following discussion, a general description of the system and its components is provided, followed by a discussion of the operation of the same.

With reference to FIG. **2**, shown is a networked environment **200** according to various embodiments. The networked environment **200** includes a computing environment **203**, a client device(s) **103**, and one or more wireless AP devices **106** which are in data communication with each other via a network **206**. The network **206** includes, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, cable networks, satellite networks, or other suitable networks, etc., or any combination of two or more such networks.

Additionally, the client device **103** and the wireless AP devices **106** may be in data communication with each other via a communication channel **209**. In some respects, the communication channel **209** can represent a direct peer-to-peer communication channel between the client device **103** and one or more wireless AP devices **106**. In some examples, the communication channel **209** can include a Wi-Fi network, a Bluetooth network, a Zigbee network, a Near Field Communication (NFC) network, and other suitable wireless protocols. In the context of the present disclosure, the communication channel **209** can also be referred to as a network for data communications.

The computing environment **203** may comprise, for example, a server computer or any other system providing computing capability. Alternatively, the computing environment **203** may employ a plurality of computing devices that may be arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices may be located in a single installation or may be distributed among many different geographical locations. For example, the computing environment **203** may include a plurality of computing devices that together may comprise a hosted computing resource, a grid computing resource, and/or any other distributed computing arrangement. In some cases, the computing environment **203** may correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time.

Various applications and/or other functionality may be executed in the computing environment **203** according to various embodiments. Also, various data is stored in a data store **215** that is accessible to the computing environment **203**. The data store **215** may be representative of a plurality of data stores **215** as can be appreciated. The data stored in the data store **215**, for example, is associated with the operation of the various applications and/or functional entities described below.

The components executed on the computing environment **203**, for example, include a confirmation service **218**, an attribute prediction engine **221**, a location confirmation engine **224**, and other applications, services, processes, systems, engines, or functionality not discussed in detail herein.

The confirmation service **218** is executed to interact with a client confirmation application **219** executed on the client device **103** to validate or otherwise confirm that the appropriate delivery driver is at the correct delivery location for a delivery of a package. In some examples, the confirmation service **218** can obtain collected wireless fingerprints **112** that are generated by a client device **103** and store the collected wireless fingerprints **112** in the data store **215** in association with the particular location for use in generating attribute prediction models **115** and location confirmation models **118**.

The confirmation service **218** can further obtain event data **230** from the client device **103** or other appropriate source. The event data **230** may comprise data associated with one or more known events (e.g., delivery of items) that are planned to occur during a given period of time with respect to a particular entity (e.g., delivery agent). For example, the event data **230** may comprise route data corresponding to the route of deliveries that a delivery agent may take during a particular day. The confirmation service **218** can use the event data **230** to determine location data for the one or more events during the given period of time. The location data can include a street address, geographic coordinates, a geo-fence boundary, and other location identifying information. The confirmation service **218** can identify generated location confirmation models **118** and attribute prediction models **115** according to the identified locations in the event data **230** and transmit the identified models to the client device **103**. As such, the client device **103** can use the location confirmation models **118** and attribute prediction models **115** for accurate location confirmation.

The attribute prediction engine **221** is executed to generate attribute prediction models **115** for a given location. The attribute prediction engine **221** can obtain samples of the collected wireless fingerprints **112** for the given location and use the collected wireless fingerprints **112** to generate the attribute prediction engine **221** according to the attribute prediction rules **239**. In some examples, the attribute prediction engine **221** analyzes the collected wireless fingerprints **112** to learn statistics associated with each AP device **106** associated with the given location and learn the covariance of each AP device **106** and its neighbor AP device **106**.

In some examples, the attribute prediction engine **221** can select a subset of available collected wireless fingerprints **112** for a given location. For example, the attribute prediction engine **221** can select a subset of available collected wireless fingerprints **112** based at least in part on a recency of collection (e.g., timestamps associated with the collected wireless fingerprints **112**), an identified change in the AP environment for a given location (e.g., addition or removal of AP device **106**), a number of required samples, a success of an associated delivery, or other factors.

The location confirmation engine **224** is executed to generate location confirmation models **118** for a given location using machine learning algorithms and other models or rules included in the location confirmation rules **236**. In particular, the location confirmation engine **224** applies the location confirmation rules **236** and uses the imputed wireless fingerprints **121** to generate location confirmation models **118** that include fingerprint models for a given location. According to various embodiments, the generated location confirmation models **118** can be used to confirm locations associated with a delivery.

The data stored in the data store **215** includes, for example, location data **233**, location confirmation models **118**, attribute prediction models **115**, location confirmation rules **236**, attribute prediction rules **239**, and potentially other data.

The location data **233** can include information associated with a given location associated with a location identifier (ID) **241**. The location identifier **241** can include a street address, geographic coordinates, a geo-fence boundary, and/or other location identifying information. In some examples, the location identifier **241** can correspond to a given location associated with a given address. For example, the location identifier **241** can correspond to an apartment number in an apartment complex, a front door of a given address, a back door of a given address, a garage location for a given address, and/or other location as can be appreciated. The location data **233** can further include the samples of collected wireless fingerprints **112** obtained from client devices **103** at the given location. The location data **233** can further include the imputed wireless fingerprints **121** that are generated using an attribute prediction model **115** that is generated for the given location.

The location confirmation models **118** include location confirmation models **118** generated by the location confirmation engine **224** for different locations. In particular, the location confirmation models **118** include fingerprint models that are generated according to various machine learning techniques defined by the location confirmation engine **224**. According to various embodiments, the location confirmation models **118** can be compared to an imputed wireless fingerprint **121** generated using a collected wireless fingerprint **112** obtained by the client device **103**. If the comparison of the imputed wireless fingerprint **121** with the location confirmation model **118** results in a score that is within a given threshold, the location can be considered to be accurate.

In some embodiments, the location confirmation models **118** can be stored in the data store **215** in association with the location data **233**. In other embodiments, the location confirmation models **118** can be stored separately in the data store **215** from the location data **233**. In other embodiments, the location confirmation models **118** may be stored in a repository or other data store that is separate from the data store **215**.

The attribute prediction models **115** may be generated by the attribute prediction engine **221** for different locations. In particular, the attribute prediction models **115** are generated to estimate missing attributes in collected wireless fingerprints **112**. For example, a given collected wireless fingerprint **112** may be generated using attributes for only a subset of AP devices **106** associated with a given location. By obtaining samples of collected wireless fingerprints **112**, patterns and statistics associated with the different AP devices **106** can be determined using the attribute prediction rules **239**. In addition, the covariance of each AP device **106** and its neighbor AP device **106** can be determined. This information in conjunction with machine learning algorithms can be used to generate attribute prediction models **115** that can estimate missing attributes for a given collected wireless fingerprint **112**. As such, the attribute prediction models **115** can be used to generate imputed wireless fingerprints **121** that reconstruct the collected wireless fingerprint **112** to include the missing attribute data.

The location confirmation rules **236** include rules, models, and/or configuration data for the various algorithms or approaches employed by the location confirmation engine **224**. For example, the location confirmation rules **236** can include the various models and/or algorithms used by the location confirmation engine **224** in generating location confirmation models **118** for a given location.

The attribute prediction rules **239** include rules, models, and/or configuration data for the various algorithms or approaches employed by the attribute prediction engine **221**. For example, the attribute prediction rules **239** can include the various models and/or algorithms used by the attribute prediction engine **221** in generating attribute prediction models **115** for a given location.

The client device **103** is representative of a plurality of client devices that may be coupled to the network **206** and/or the communication channel **209**. The client device **103** may comprise, for example, a processor-based system such as a computer system. Such a computer system may be embodied in the form of a desktop computer, a laptop computer, personal digital assistants, cellular telephones, smartphones, set-top boxes, music players, web pads, tablet computer systems, game consoles, electronic book readers, smartwatches, head mounted displays, voice interface devices, or other devices. The client device **103** may include a display **244**. The display **244** may comprise, for example, one or more devices such as liquid crystal display (LCD) displays, gas plasma-based flat panel displays, organic light emitting diode (OLED) displays, electrophoretic ink (E ink) displays, LCD projectors, other types of display devices, etc.

The client device **103** can also include a radio frequency (RF) transceiver **247** for communicating via the network **206** and/or the communication channel **209**. The RF transceiver **247** can be representative of a plurality of different transceivers in the client device **103**, such as a Wi-Fi transceiver, a Bluetooth transceiver, Zigbee transceiver, a cellular transceiver, a Near Field Communication (NFC) transceiver, a radio frequency identification (RFID) transceiver, or other suitable transceivers. The client device **103** can also be equipped with a microphone, a speaker, a light emitting device, a location detecting device (e.g., a GPS unit), sensors, and other suitable components for a mobile device.

The client device **103** may be configured to execute various applications such as client application(s) **250**, the client confirmation application **227**, and/or other applications. The client application(s) **250** may be executed in a client device **103**, for example, to access network content served up by the computing environment **203** and/or other servers, thereby rendering a user interface **253** on the display **244**. To this end, the client application **250** may comprise, for example, a browser, a dedicated application, etc., and the user interface **253** may comprise a network page, an application screen, etc. The client device **103** may be configured to execute applications beyond the client application **250** such as, for example, email applications, social networking applications, word processors, spreadsheets, and/or other applications.

The client confirmation application **227** can comprise a client application **250** that interacts with the confirmation service **218** in the computing environment **203**. For example, the client confirmation application **227** can obtain location confirmation models **118** and attribute prediction models **115** from the confirmation service **218** for locations defined in the event data **230**. The client confirmation application **227** can identify AP devices **106** associated with a given location and generate a collected wireless fingerprint **112** using the attribute data **259** obtained from the identified AP devices **106**. In various embodiments, the client confirmation application **227** can generate an imputed wireless fingerprint **121** using the obtained attribute prediction model **115** for the given location and the collected wireless fingerprint **112**. Upon generating the imputed wireless fingerprint **121**, the client confirmation application **227** can compare the imputed wireless fingerprint **121** with the obtained location confirmation model **118** for the given location to confirm an accuracy of the client device location.

Also, various data is stored in a client data store **256** that is accessible to the client device **103**. The client data store **256** may be representative of a plurality of data stores as can be appreciated. The data stored in the client data store **256**, for example, is associated with the operation of various applications and/or functional entities described herein. The client data store **256** may store data received from the computing environment **203** and/or the AP device **106**, such as event data **230**, location confirmation models **118**, attribute prediction models **115**, attribute data **259**, and other data as can be appreciated.

The wireless AP device **106** is representative of a plurality of client devices that may be coupled to the network **206** and/or the communication channel **209**. In some examples, the wireless AP device **106** may comprises one of the client devices **103**. The wireless AP device **106** can refer to a network access point that provides the client devices **103** with access to corresponding networks. The wireless AP device **106** may also comprise, for example, a processor-based system such as a computer system. Such a computer system may be embodied in the form of a desktop computer, a laptop computer, personal digital assistants, cellular telephones, smartphones, set-top boxes, music players, web pads, tablet computer systems, game consoles, electronic book readers, or other devices with like capability.

The wireless AP device **106** can also include a transceiver **262** for communicating via the network **206** and/or the communication channel **209**. The transceiver **262** can represent a hardware component capable of wired or wireless data communication. The transceiver **262** can be representative of a plurality of different transceivers in the wireless AP device **106**, such as an Ethernet transceiver, a Wi-Fi transceiver, a Bluetooth transceiver, Zigbee transceiver, a Near Field Communication (NFC) transceiver, a radio frequency identification (RFID) transceiver or other suitable transceivers.

Also, various data is stored in an AP data store **265** that is accessible to the wireless AP device **106**. The AP data store **265** may be representative of a plurality of AP data stores **265** as can be appreciated. The data stored in the AP data store **265**, for example, is associated with the operation of the various applications and/or functional entities described herein. The AP data store **265** may include attribute data **259** and other client data. The attribute data **259** can include an SSID, BSSID, location identifier **241**, signal strength, type of device, and/or other data.

Next, a general description of the operation of the various components of the networked environment **200** is provided with reference to FIGS. **3**-**6**. To begin, FIG. **3** illustrates a flowchart **300** that provides one example of the operation of portions of the confirmation service **218** (FIG. **2**), the attribute prediction engine **221** (FIG. **2**), and the location confirmation engine **224** (FIG. **2**) according to various embodiments. It is understood that the flowchart of FIG. **3** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portions of the confirmation service **218**, the attribute prediction engine **221**, and the location confirmation engine **224** as described herein. As an alternative, the flowchart of FIG. **3** may be viewed as depicting an example of elements of a method implemented in the computing environment **203** (FIG. **2**) according to one or more embodiments.

FIG. **3** provides a non-limiting example of the functionality that may be performed by the confirmation service **218**, the attribute prediction engine **221**, and the location confirmation engine **224** during the survey phase of wireless localization. Specifically, FIG. **3** provides a non-limiting example of collecting wireless fingerprints **112** (FIG. **1**), training attribute prediction models **115** (FIG. **1**) based on the collected wireless fingerprints **112**, and training location confirmation models **118** (FIG. **2**) according to imputed wireless fingerprints **121** (FIG. **2**) that include missing attribute data **259** (FIG. **2**) estimated using the trained attribute prediction models **115**.

At box **303**, the confirmation service **218** collects samples of collected wireless fingerprints **112** according to various embodiments. The wireless fingerprints **112** may be received by a client device **103** (FIG. **1**) that generates the wireless fingerprints **112** in response to performing a wireless scan to obtain attribute data **259** from surrounding AP devices **106** (FIG. **1**) in the surrounding area **109** (FIG. **1**) of the location of the client device **103**. The wireless fingerprints **112** can be generated by the client device **103** in response to an individual arbitrarily walking around the proximity of the target location and using his or her client device **103** to collect the samples, by performing a delivery of an item at the target location, and/or other method of collecting samples, as can be appreciated. In some examples, the samples are collected based at least in part user interaction with his or her client device. In other examples, the samples are collected in the background without user intervention. In response to generating the collected wireless fingerprints **112**, the client confirmation application **227** (FIG. **2**) can transmit the collected wireless fingerprints **112** to the confirmation service **218**. In various embodiments, the confirmation service **218** stores the received collected wireless fingerprints **112** in the data store **215**.

At box **306**, the attribute prediction engine **221** can identify and/or analyze the attributes of each received collected wireless fingerprint **112**. For example, the attributes can include the signal strength (e.g., RSSI), a location of the identified AP device **106**, a device identifier (e.g., BSSID, SSID), and other attributes as can be appreciated.

At box **309**, the attribute prediction engine **221** may select at least a subset of the collected wireless fingerprints **112** for the given location. The selected wireless fingerprints **112** can be used for training the attribute prediction model **115** for the given location. For example, selection of the collected wireless fingerprints **112** can be based at least in part on a recency of collection (e.g., timestamps associated with the collected wireless fingerprints **112**), an identified change in the AP environment for a given location (e.g., addition or removal of AP device **106**), a number of required samples, a success of an associated delivery at the given location, and/or other factors.

At box **312**, the attribute prediction engine **221** trains the attribute prediction model **115** to learn how to reconstruct missing signal attributes from unseen AP devices **106**. In particular, a matrix can be constructed for the collected wireless fingerprints **112**, collected from a location where the rows are the fingerprints and columns are different AP devices **106**. Due to the software and hardware limitations for devices with respect to wireless localization and scanning for AP devices **106**, each collected wireless fingerprint **112** may include attributes for only a partial list of AP devices **106**, leaving missing values in this matrix. Therefore, collaborative filtering algorithms can be applied to predict the missing values in the matrix.

Given a matrix $\psi \in \mathbb{R}^{m \times n}$ defined as

$$\Psi = \begin{bmatrix} \psi_{1,1} & \cdots & \psi_{1,n} \\ \vdots & \ddots & \vdots \\ \psi_{m,1} & \cdots & \psi_{m,n} \end{bmatrix}$$

where n is the number of AP devices **106** and m is the number of collected wireless fingerprints **112**. Each entry is the RSSI value ranging from 0 to −110 dB. According to matrix factorization, this matrix can be decomposed into two components as

$$\Psi = P \times Q^T$$

where $P \in \mathbb{R}^{m \times k}$ and $Q \in \mathbb{R}^{n \times k}$ and k are the number of latent variables. In this matrix decomposition, the fingerprint (FP)-factor P and AP-factor Q are decoupled using the latent variables. In essence, the latent variables capture the joint distribution and dynamics of the AP variations and reflect the effects on the observed fingerprint samples. In this setup, each element in the matrix can be written as

$$\psi_{i,j} = \sum_{k=1}^{K} p_{i,k} q_{k,j}$$

In reality, such decomposition will not have a closed form solution for most cases due to the sparsity of the Ψ matrix. As such, the decomposition can be solved by the best estimation where

$$\Psi \approx \tilde{\Psi} = \tilde{P} \times \tilde{Q}^T$$

The estimation can be solved by gradient descent by optimization of the following objective function:

$$e_{i,j}^2 = \left(\psi_{i,j} - \tilde{\psi}_{i,j}\right)^2 = \left(\psi_{i,j} - \sum_{k=1}^{K} \tilde{p}_{i,k} \tilde{q}_{k,j}\right)^2$$

$$s.t. \psi_{ij} \text{ is NOT missing}$$

Inaccurate signal strength (e.g., RSSI) value estimation can have severe negative impact to the accuracy of location confirmation. Therefore, metrics are designed to evaluate the confidence of each signal strength value estimation from matrix factorization. For each $\tilde{P}$ and $\tilde{Q}$, the corresponding confidence matrices $\check{P}$ and $\check{Q}$ can be constructed such that

$$\check{P}_{i,j} = \frac{\theta_{i,j}^P}{\Theta^P}, \check{Q}_{i,j} = \frac{\Theta_{i,j}^Q}{\Theta^Q}$$

where Θ is the maximum number of updates for each gradient descent iteration and $\theta_{i,j}$ is the actual updates received for each parameter. Together, the confidence of the estimation is

$$\check{\Psi} = \check{P} \times \check{Q}^T$$

Finally, the matrix after data imputation is

$$\psi_{i,j} = \begin{cases} \tilde{\psi}_{i,j}, & \psi_{i,j} \text{ is missing } \wedge \check{\Psi}_{i,j} \geq \tau \\ \psi_{i,j}, & \text{otherwise} \end{cases}$$

where τ is the confidence threshold.

At box **315**, the attribute prediction engine **221** generates imputed wireless fingerprints **121** according to various embodiments of the present disclosure. The imputed wireless fingerprints **121** can be generated from a subset of collected wireless fingerprints **112** collected during the survey phase. In some examples, the imputed wireless fingerprints **121** are generated using one or more of the collected wireless fingerprints **112** used to train the attribute prediction model **115**. In other examples, the imputed wireless fingerprints **121** are generated using samples of collected wireless fingerprints **112** that were not selected for training the attribute prediction model **115**. The imputed wireless fingerprints **121** are generated to include the missing attributes of the unseen AP devices **106** according to the attribute prediction model **115**.

At box **318**, the location confirmation engine **224** trains a location confirmation model **118** for the given location according to the location confirmation rules **236** and imputed wireless fingerprints **121** generated for training the location confirmation model **118**. In particular, the location confirmation engine **224** can use the imputed wireless fingerprints **121** that are generated to include the missing attribute data **259** of the unseen AP devices **106**. The generated location confirmation model **118** for the given location can be compared to a wireless fingerprint obtained during the online phase of wireless localization.

At box **321**, the location confirmation engine **224** stores the location confirmation model **118** for the given location in the data store **215**. Thereafter, this portion of the process proceeds to completion.

Referring next to FIG. **4**, shown is a flowchart **400** that provides one example of the operation of a portion of the client confirmation application **227** (FIG. **2**) according to various embodiments. It is understood that the flowchart of FIG. **4** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the client confirmation application **227** as described herein. As an alternative, the flowchart of FIG. **4** may be viewed as depicting an example of elements of a method implemented in the client device **103** (FIG. **1**) according to one or more embodiments.

FIG. **4** provides a non-limiting example of the functionality that may be performed by the client confirmation application **227** during the online phase of wireless localization. Specifically, FIG. **4** provides a non-limiting example of generating a wireless fingerprint **112** (FIG. **1**) and using a pretrained attribute prediction model **115** (FIG. **1**) and a pretrained location confirmation model for the given location to confirm accuracy of the location using the generated wireless fingerprint **112**.

Beginning with box **403**, the client confirmation application **227** can perform a wireless scan (e.g., a Wi-Fi scan) to identify wireless AP devices **106** (FIG. **1**) in the surrounding area **109** (FIG. **1**). The client confirmation application **227** can perform an active or passive wireless scan to identify AP devices **106** and obtain attribute data **259** (e.g., signal strength, device identifier, AP device location, etc.). For example, in active scanning, the client confirmation application **227** via the transceiver **247** can transmit a request for AP devices **106** and then can identify AP devices **106** in response to received responses. In passive scanning, the client confirmation application **227** via the transceiver **247** may listen for broadcasts from AP devices **106** through different channels.

At box **406**, the client confirmation application **227** can obtain the attribute data **259** from the identified AP devices **106**. The attribute data **259** (FIG. **2**) may be included in the response and/or broadcast received from the AP device **106** upon identification. In some examples, the attribute data **259** is received following an additional request to the identified AP devices **106**.

At box **409**, the client confirmation application **227** generates a collected wireless fingerprint **112** using the attribute data **259** obtained from the identified AP devices **106**. Since the client confirmation application **227** likely fails to identify all AP devices **106** in the surrounding area **109** and/or the client confirmation application **227** fails to receive attribute data **259** from all of the identified AP devices **106**, the collected wireless fingerprint **112** is incomplete as it is missing attribute data **259** for unseen AP devices **106**.

At box **412**, the client confirmation application **227** reconstructs the collected wireless fingerprint **112** to include the estimated missing attribute data **259** and thereby generate an imputed wireless fingerprint **121** (FIG. **1**) according to various examples of the present disclosure. In particular, the client confirmation application **227** can apply a previously trained attribute prediction model **115** for the given location to the collected wireless fingerprint **112** to generate the imputed wireless fingerprint **121**. In some examples, the client confirmation application **227** can request the attribute prediction model **115** for the given location from the confirmation service **218** (FIG. **2**). In other examples, the client confirmation application **227** obtains the attribute prediction models **115** for all delivery locations for a given time period from the confirmation service **218**, in response to providing the confirmation service **218** the event data **230** (FIG. **2**) associated with the given time period.

At box **415**, the client confirmation application **227** compares the imputed wireless fingerprint **121** to a trained location confirmation model **118** (FIG. **2**) to determine if the location of the client device **103** (e.g., delivery agent) is correct. In some examples, the client confirmation application **227** can request the location confirmation model **118** for the given location from the confirmation service **218**. In other examples, the client confirmation application **227** obtains the location confirmation models **118** for all delivery locations for a given time period from the confirmation service **218**, in response to providing the confirmation service **218** the event data **230** for the given time period.

At box **418**, the client confirmation application **227** determines with the comparison is within a predefined threshold that is defined in the location confirmation rules **236** (FIG. **2**). For example, the client confirmation application **227** can determine a similarity score generated in response to the comparison of the imputed wireless fingerprint **121** with the location confirmation model **118**. If the similarity score is within the predefined threshold defined in the location confirmation rules **236**, the location is determined to be correct and the process proceeds to box **421**. However, if the similarity score is outside of the predefined threshold, the location may be determined to be incorrect and the process proceeds to box **424**.

At box **421**, the client confirmation application **227** generates a notification indicating that the location is a correct location. Upon generating the notification, the client confirmation application **227** can cause the notification to be rendered on the client device **103** to notify the user (e.g., delivery agent) associated with the client device **103**, accordingly. Thereafter, this portion of the process proceeds to completion.

At box **424**, the client confirmation application **227** generates a notification indicating that the location associated with the client device **103** is an incorrect location. Upon generating the notification, the client confirmation application **227** can cause the notification to be rendered on the client device **103** to notify the user (e.g., delivery agent) associated with the client device **103**, accordingly. Thereafter, this portion of the process proceeds to completion.

Referring next to FIG. **5**, shown is a flowchart that provides one example of the operation of the portions of the confirmation service **218** (FIG. **2**), the attribute prediction engine **221** (FIG. **2**), and the location confirmation engine **224** (FIG. **2**) according to various embodiments. It is understood that the flowchart of FIG. **5** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portions of the confirmation service **218**, the attribute prediction engine **221**, and the location confirmation engine **224** as described herein. As an alternative, the flowchart of FIG. **5** may be viewed as depicting an example of elements of a method implemented in the computing environment **203** (FIG. **2**) according to one or more embodiments.

FIG. **5** provides a non-limiting example of the functionality that may be performed by the confirmation service **218**, the attribute prediction engine **221**, and the location confirmation engine **224** during an update of the survey phase of wireless localization. Specifically, FIG. **5** provides a non-limiting example of updating the attribute prediction models **115** (FIG. **1**) and location confirmation models **118** (FIG. **2**) for different locations according to various embodiments of the present disclosure.

Beginning with box **503**, the confirmation service **218** determines whether an attribute prediction model **115** requires an update. The confirmation service **218** can determine that the attribute prediction model **115** requires an update in response to determining that the previously trained attribute prediction model **115** is outdated, a periodic frequency (e.g., daily, weekly, monthly), and/or other factors as can be appreciated. The previously trained attribute prediction model **115** can be considered outdated according to an analysis of various factors including, for example, a timestamp associated with the creation of the attribute prediction model **115** being outside a predefined threshold, an identification of an addition of one or more AP devices **106** (FIG. **1**) in the surrounding area **109** (FIG. **1**), an identification of a removal of one or more AP devices **106** in the surrounding area **109**, a number of complaints received of incorrect deliveries, and/or other factors. If the confirmation service **218** determines that an update is required, the confirmation service proceeds to box **506**. Otherwise, the confirmation service **218** remains at box **503** until an update is determined to be required.

At box **506**, the attribute prediction engine **221** can analyze the attributes of each received collected wireless fingerprint **112** (FIG. **1**). For example, the attributes can include the signal strength (e.g., RSSI), a location of the identified AP device **106**, a device identifier (e.g., BSSID, SSID), a timestamp associated with the generation of the wireless fingerprint **112**, and other attributes as can be appreciated.

At box **509**, the attribute prediction engine **221** selects a subset of collected wireless fingerprint samples stored in the data store **215** (FIG. **2**). According to various embodiments, the attribute prediction engine **221** may select at least a subset of the collected wireless fingerprints **112** for the given location. The selected wireless fingerprints **112** can be used for updating the attribute prediction model **115** for the given location. For example, selection of the collected wireless fingerprints **112** can be based at least in part on a recency of collection (e.g., timestamps associated with the collected wireless fingerprints **112**), an identified change in the AP environment for a given location (e.g., addition or removal of AP device **106**), and whether a particular collected wireless fingerprint **112** includes attribute data **259** (FIG. **2**) associated with the added or removed AP device **106**, a number of required samples, a success of an associated delivery at the given location, and/or other factors.

At box **512**, the attribute prediction engine **221** updates the attribute prediction model **115** for the given location according to the selected collected wireless fingerprints **112**. For example, the attribute prediction engine **221** can retrain the attribute prediction model **115** according to a description set forth in box **312** of FIG. **3**.

At box **515**, the attribute prediction engine **221** generates updated imputed wireless fingerprints **121** (FIG. **1**). The imputed wireless fingerprints **121** can be generated from a subset of collected wireless fingerprints **112** over a period of time. In some examples, the updated imputed wireless fingerprints **121** are generated using one or more of the collected wireless fingerprints **112** used to update the attribute prediction model **115**. In other examples, the updated imputed wireless fingerprints **121** are generated using samples of collected wireless fingerprints **112** that were not selected for updating the attribute prediction model **115**. The updated imputed wireless fingerprints **121** are generated to include the missing attributes of the unseen AP devices **106** according to the attribute prediction model **115**.

At box **518**, the location confirmation engine **224** updates the location confirmation model **118** for the given location according to the location confirmation rules **236** (FIG. **2**), and updated imputed wireless fingerprints **121** generated for training the location confirmation model **118**. In particular, the location confirmation engine **224** can use the updated imputed wireless fingerprints **121** that are generated to include the missing attribute data **259** of the unseen AP devices **106**.

At box **521**, the location confirmation engine **224** stores the location confirmation model **118** for the given location in the data store **215**. In addition, the attribute prediction engine **221** may store the updated attribute prediction model **115** in association with the given location in the data store **215**. Thereafter, this portion of the process proceeds to completion.

Referring next to FIG. **6**, shown is a flowchart that provides one example of the operation of a portion of the confirmation service **218** (FIG. **2**) according to various embodiments. It is understood that the flowchart of FIG. **6** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the confirmation service **218** as described herein. As an alternative, the flowchart of FIG. **6** may be viewed as depicting an example of elements of a method implemented in the computing environment **203** (FIG. **2**) according to one or more embodiments.

Beginning with box **603**, the confirmation service **218** obtains event data **230** (FIG. **2**) associated with a client device **103** (FIG. **1**). For example, the client device **103** may be associated with a delivery agent and the event data **230** includes the different delivery locations that the delivery agent is scheduled to deliver items at during a predefined period of time (e.g., day, week, range of hours, etc.). In some examples, the confirmation service **218** can obtain the event data **230** upon a request to the client device **103**. In other examples, the event data **230** may be stored in the data store **215** FIG. **2**) in association with the delivery agent data, device data, and/or other appropriate data. In this example, the confirmation service **218** may obtain the event data **230** in response to a request to the data store **215**.

At box **606**, the confirmation service **218** identifies the pretrained attribute prediction models **115** (FIG. **1**) and location confirmation models **118** (FIG. **2**) that are associated with the delivery locations extracted from the event data **230**. For example, the attribute prediction models **115** and location confirmation models **118** are associated with location identifiers **241** (FIG. **2**) for a given location. By being able to match the location identifiers **241** for the attribute prediction models and location confirmation models **118** with the location identifiers **241** included in the event data **230**, the confirmation service **218** can identify the appropriate models.

At box **609**, the confirmation service **218** transmits the identified pretrained attribute prediction models **115** and the pretrained location confirmation models **118** for the different locations to the client device **103**. Transmitting the attribute prediction models and location confirmation models **118** in advance and in batch to the client device **103** can reduce the processing time and reduce network traffic required associated with each delivery confirmation action performed by the client device **103**. Thereafter, this portion of the process proceeds to completion.

With reference to FIG. **7**, shown is a schematic block diagram of the computing environment **203** according to an embodiment of the present disclosure. The computing environment **203** includes one or more computing devices **703** Each computing device **703** includes at least one processor circuit, for example, having a processor **706** and a memory **709**, both of which are coupled to a local interface **712**. To this end, each computing device **703** may comprise, for example, at least one server computer or like device. The local interface **712** may comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

Stored in the memory **709** are both data and several components that are executable by the processor **706**. In particular, stored in the memory **709** and executable by the processor **706** are a confirmation service **218**, an attribute prediction engine **221**, a location confirmation engine **224**, and potentially other applications. Also stored in the memory **709** may be a data store **215** and other data. In addition, an operating system may be stored in the memory **709** and executable by the processor **706**.

With reference to FIG. **8**, shown is a schematic block diagram of the client device **103** (FIG. **1**) according to an embodiment of the present disclosure. The client device **103** includes at least one processor circuit, for example, having a processor **803** and a memory **806**, both of which are coupled to a local interface **809**. The local interface **809** may comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated. A display **244** may also be coupled to the local interface **809**.

Stored in the memory **806** are both data and several components that are executable by the processor **803**. In particular, stored in the memory **806** and executable by the processor **803** are client applications **250**, a client confirmation application **227**, and potentially other applications. Also stored in the memory **806** may be a data store and other data. In addition, an operating system may be stored in the memory **806** and executable by the processor **803**.

Referring now to both FIGS. **7** and **8**, it is understood that there may be other applications that are stored in the memory **709**, **806** and are executable by the processor **706**, **803** as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed such as, for example, C, C++, C#, Objective C, Java®, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Flash®, or other programming languages.

A number of software components are stored in the memory **709**, **806** and are executable by the processor **706**, **803**. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor **706**, **803**. Examples of executable programs may be, for example, a compiled program that can be translated into machine code in a format that can be loaded into a random access portion of the memory **709**, **806** and run by the processor **706**, **803**, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory **709**, **806** and executed by the processor **706**, **803**, or source code that may be interpreted by another executable program to generate instructions in a random access portion of the memory **709**, **806** to be executed by the processor **706**, **803**, etc. An executable program may be stored in any portion or component of the memory **709**, **806** including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, USB flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other memory components.

The memory **709**, **806** is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory **709**, **806** may comprise, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, and/or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may comprise, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may comprise, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

Also, the processor **706**, **803** may represent multiple processors **706**, **803** and/or multiple processor cores and the memory **709**, **806** may represent multiple memories **709**, **806** that operate in parallel processing circuits, respectively. In such a case, the local interface **712**, **809** may be an appropriate network that facilitates communication between any two of the multiple processors **706**, **803**, between any processor **706**, **803** and any of the memories **709**, **806**, or between any two of the memories **709**, **806**, etc. The local interface **712**, **809** may comprise additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor **706**, **803** may be of electrical or of some other available construction.

Although the confirmation service **218**, the attribute prediction engine **221**, the location confirmation engine **224**, the client confirmation application **227**, and other various systems described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, etc. Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

The flowcharts of FIGS. **3-6** show the functionality and operation of an implementation of portions of the confirmation service **218**, the attribute prediction engine **221**, the location confirmation engine **224**, and the client confirmation application **227**. If embodied in software, each block may represent a module, segment, or portion of code that comprises program instructions to implement the specified logical function(s). The program instructions may be embodied in the form of source code that comprises human-readable statements written in a programming language or machine code that comprises numerical instructions recognizable by a suitable execution system such as a processor **706**, **803** in a computer system or other system. The machine code may be converted from the source code, etc. If embodied in hardware, each block may represent a circuit or a number of interconnected circuits to implement the specified logical function(s).

Although the flowcharts of FIGS. **3-6** show a specific order of execution, it is understood that the order of execution may differ from that which is depicted. For example, the order of execution of two or more blocks may be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIGS. **3-6** may be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the blocks shown in FIGS. **3-6** may be skipped or omitted. In addition, any number of counters, state variables, warning semaphores, or messages might be added to the logical flow described herein, for purposes of enhanced utility, accounting, performance measurement, or providing troubleshooting aids, etc. It is understood that all such variations are within the scope of the present disclosure.

Also, any logic or application described herein, including the confirmation service **218**, the attribute prediction engine **221**, the location confirmation engine **224**, the client confirmation application **227**, that comprises software or code can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor **706**, **803** in a computer system or other system. In this sense, the logic may comprise, for example, statements including instructions and declarations that can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a "computer-readable medium" can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

The computer-readable medium can comprise any one of many physical media such as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM) and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

Further, any logic or application described herein, including the confirmation service **218**, the attribute prediction engine **221**, the location confirmation engine **224**, the client confirmation application **227**, may be implemented and structured in a variety of ways. For example, one or more applications described may be implemented as modules or components of a single application. Further, one or more applications described herein may be executed in shared or separate computing devices or a combination thereof. For example, a plurality of the applications described herein may execute in the same computing device **703**, or in multiple computing devices **703** in the same computing environment **203**.

Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

Therefore, the following is claimed:

1. A system, comprising:

at least one computing device; and

at least one application executable on the at least one computing device, wherein, when executed, the at least one application causes the at least one computing device to at least:

collect a plurality of wireless fingerprints associated with a particular location based at least in part on a plurality of item deliveries associated with the particular location, individual wireless fingerprints of the plurality of wireless fingerprints comprising one or more attributes associated with a respective subset of wireless access points of a plurality of wireless access points located within a predefined area of the particular location;

generate an attribute prediction model based at least in part on the plurality of wireless fingerprints, the attribute prediction model being configured to estimate one or more missing attributes associated with individual wireless access points of the plurality of wireless access points that are missing from the respective subset of wireless access points of the individual wireless fingerprints;

generate a plurality of imputed wireless fingerprints based at least in part on the attribute prediction model and the plurality of collected wireless fingerprints, individual imputed wireless fingerprints of the plurality of imputed wireless fingerprints including an estimation of the one or more missing attributes for the individual wireless access points missing from the respective subset of wireless access points;

generate a location confirmation model for the particular location based on the plurality of imputed wireless fingerprints; and

transmit the attribute prediction model and the location confirmation model to a client device, the client device being configured to confirm an accuracy of a delivery of an item at the particular location based at least in part on the attribute prediction model and the location confirmation model.

2. The system of claim **1**, wherein the one or more attributes include a device identifier, a signal strength, and corresponding locations of the respective subset of wireless access points.

3. The system of claim **1**, wherein, when executed, the at least one application further causes the at least one computing device to at least store the attribute prediction model and the location confirmation model in a data store in association with a location identifier of the particular location.

4. The system of claim **1**, wherein a first subset of wireless access points associated with a first wireless fingerprint excludes at least one wireless access point that is included in a second subset of wireless access points associated with a second wireless fingerprint.

5. A method, comprising:

collecting, by at least one computing device, a plurality of wireless fingerprints associated with a particular location based at least in part on a plurality of item deliveries associated with the particular location, individual wireless fingerprints of the plurality of wireless fingerprints comprising one or more attributes associated with a respective subset of wireless access points of a plurality of wireless access points located within a predefined area of the particular location;

generating, by the at least one computing device, an attribute prediction model based at least in part on the plurality of wireless fingerprints, the attribute prediction model being configured to estimate one or more missing attributes associated with individual wireless fingerprints of the plurality of wireless access points that are missing from the respective subset of wireless access points of the individual wireless fingerprints;

modifying, by the at least one computing device, the plurality of wireless fingerprints to include an estimation of the one or more missing attributes for the individual wireless access points missing from the respective subset of wireless access points, the plurality of wireless fingerprints being modified based at least in part on the attribute prediction model;

generating, by the at least one computing device, a location confirmation model for the particular location based at least in part on the plurality of modified wireless fingerprints; and

confirming an accuracy of a delivery of an item at the particular location based at least in part on the attribute prediction model and the location confirmation model.

6. The method of claim **5**, wherein the plurality of wireless fingerprints are collected over a period of time based at least in part on the plurality of item deliveries associated with the particular location.

7. The method of claim **5**, further comprising receiving, by the at least one computing device, the individual wireless fingerprints from at least one client device.

8. The method of claim **5**, wherein generating the attribute prediction model further comprises determining a respective correlation between at least two wireless access points of the plurality of wireless access points based at least in part on at least one of a variation of signal strength between the at least two wireless access points or a respective distance between a respective wireless access point of the at least two wireless access points and the particular location.

9. The method of claim **5**, further comprising:

generating model data comprising the attribute prediction model and the location confirmation model; and

transmitting the model data to a client device.

10. The method of claim **9**, further comprising:

receiving event data associated with the client device; and determining that the particular location is included in the event data, wherein the model data is transmitted to the client device in response to determining that the particular location is included in the event data.

11. The method of claim **5**, wherein the plurality of wireless fingerprints comprises a first plurality of wireless fingerprints and further comprising:

determining that the attribute prediction model is to be updated; and

in response to determining that the attribute prediction model is to be updated:

updating the attribute prediction model based at least in part on a second plurality of wireless fingerprints; and

modifying the second plurality of wireless fingerprints based at least in part on the updated attribute prediction model; and

updating the location confirmation model based at least in part on the modified second plurality of wireless fingerprints.

12. The method of claim **11**, wherein determining that the attribute prediction model is to be updated is based at least in part on at least one of a number of wireless fingerprints meeting or exceeding a predefined threshold or a respective timestamp associated with a respective wireless fingerprint of the plurality of wireless fingerprints.

13. The method of claim **11**, wherein determining that the attribute prediction model is to be updated is based at least in part on a periodic frequency.

14. A system, comprising:

a client device; and

at least one application executable in the client device, wherein when executed the at least one application causes the client device to at least:

collect a plurality of wireless fingerprints associated with a particular location based at least in part on a plurality of item deliveries associated with the particular location, individual wireless fingerprints of the plurality of wireless fingerprints comprising one or more attributes associated with a respective subset of wireless access points of a plurality of wireless access points located within a predefined area of the particular location;

generate a first wireless fingerprint based at least in part on attribute data associated with a first subset of wireless devices of a plurality of wireless devices associated with a client device location corresponding to the plurality of item deliveries, the first wireless fingerprint missing attribute data for a second subset of wireless devices of the plurality of wireless devices;

estimate the missing attribute data for the second subset of wireless devices based at least in part on an attribute prediction model, the attribute prediction model being configured to estimate one or more missing attributes associated with individual wireless access points of the plurality of wireless access points that are missing from the respective subset of wireless access points of the individual wireless fingerprints;

generate a second wireless fingerprint based at least in part on the estimated missing attribute data of the attribute prediction model and the first wireless fingerprint, including an estimation of the one or more missing attributes for the individual wireless access points missing from the respective subset of wireless access points;

generate a location confirmation model for the particular location based at least in part on the second wireless fingerprint; and

confirm that the client device location is within a predefined area associated with a delivery of an item at the particular location based at least in part on the second wireless fingerprint and the location confirmation model.

15. The system of claim **14**, wherein the attribute data comprises at least one of a respective device identifier of a respective wireless access point device of the first subset of wireless devices, a wireless access point device location, and a signal strength of a respective wireless device.

16. The system of claim **14**, wherein, when executed, the at least one application further causes the client device to at least:

receive a request from at least one computing device for event data associated with the client device; and

provide the event data to the at least one computing device.

17. The system of claim **16**, wherein, when executed, the at least one application further causes the client device to at least receive the location confirmation model and the attribute prediction model for the particular location from the at least one computing device based at least in part on the event data.

18. The system of claim **14**, wherein, when executed, the at least one application causes the client device to at least:

generate a notification indicating an accuracy of the client device location with respect to the particular location; and

render the notification on a display of the client device.

19. The system of claim **14**, wherein, when executed, the at least one application causes the client device to at least:

identify the first subset of wireless devices; and

obtain the attribute data being broadcasted from the first subset of wireless devices.

20. The system of claim **14**, wherein the attribute prediction model is generated based at least in part on a plurality of previously collected wireless fingerprints associated with the particular location.

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