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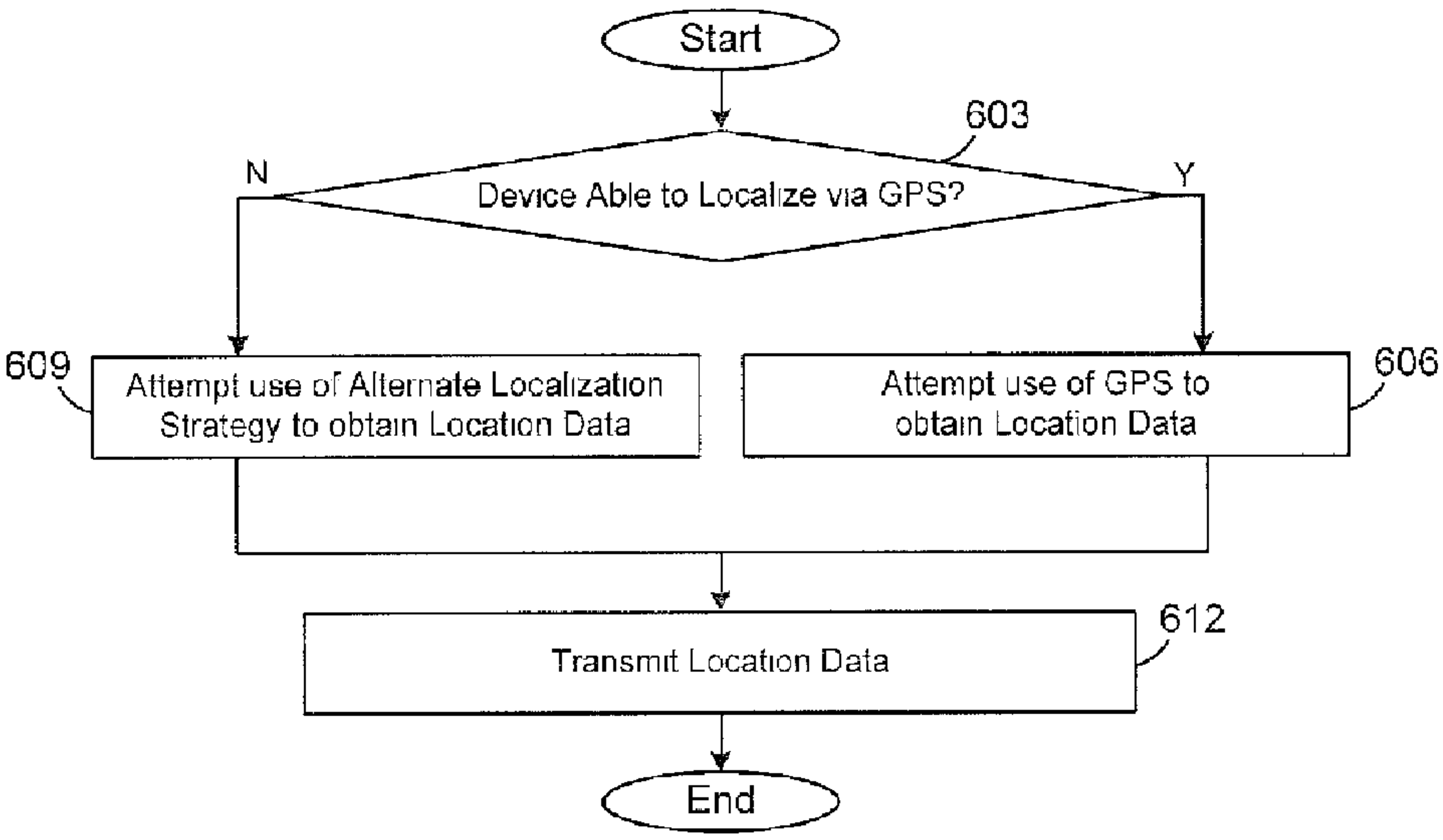

FIG. 6

(57) Abrégé/Abstract:
Disclosed are various embodiments for monitoring tracking devices capable of seamless indoor and outdoor tracking transitions. A tracking device can comprise, for example, printable circuitry and antennas combined with one or more receivers/transceivers on a substrate. The tracking device can be configured, for example, to localize the tracking device via GPS or an alternative localization strategy based on a determination of whether GPS communication is available. A modified RSSI fingerprinting methodology can be used to accurately determine a location of the tracking device using Wi-Fi access points. A device monitoring service can communicate with internal and/or external mapping API's to render a device monitoring user interface comprising a visual representation of the location of the tracking device.

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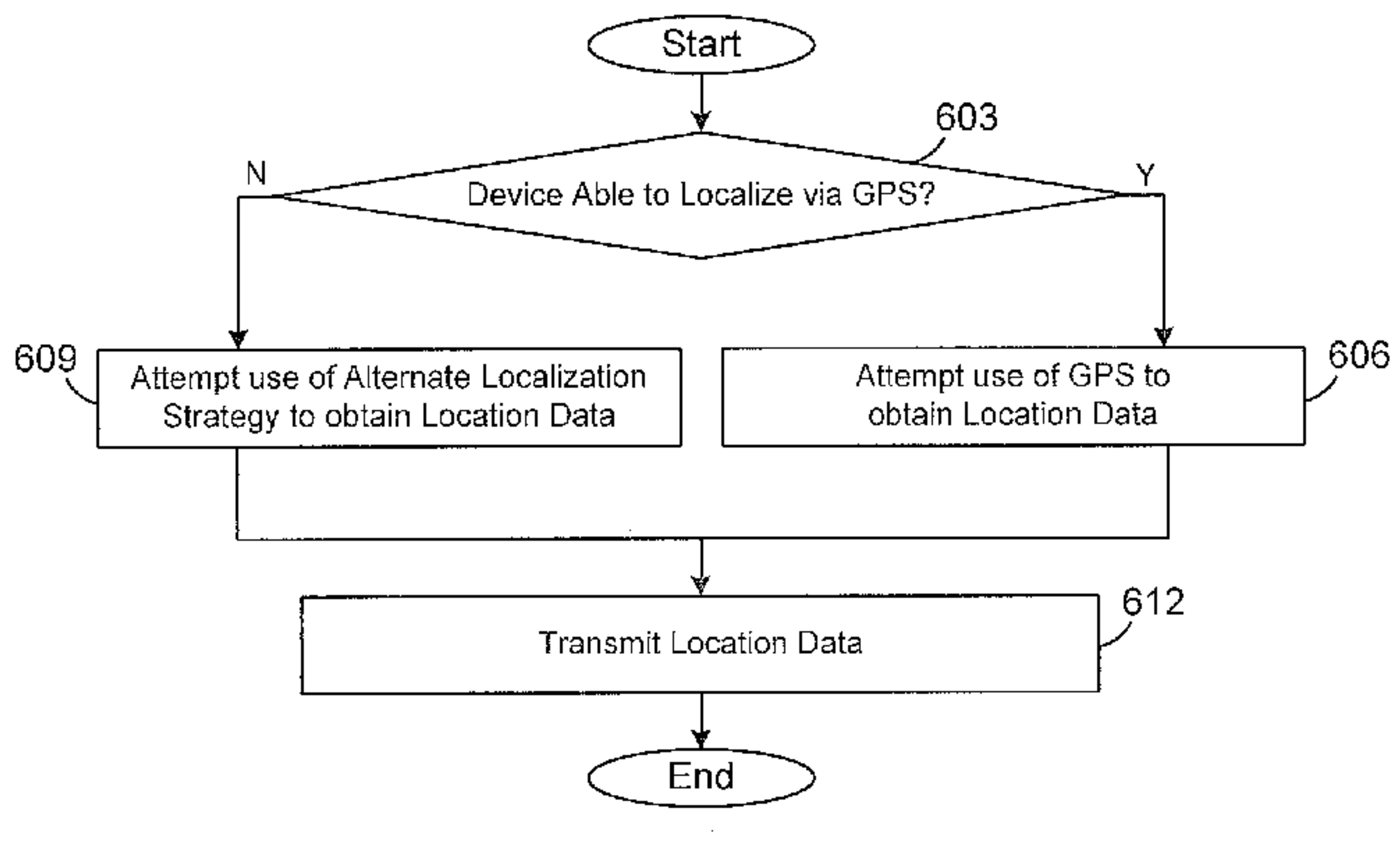

FIG. 6

(57) **Abstract**: Disclosed are various embodiments for monitoring tracking devices capable of seamless indoor and outdoor tracking transitions. A tracking device can comprise, for example, printable circuitry and antennas combined with one or more receivers/transceivers on a substrate. The tracking device can be configured, for example, to localize the tracking device via GPS or an alternative localization strategy based on a determination of whether GPS communication is available. A modified RSSI finger-printing methodology can be used to accurately determine a location of the tracking device using Wi-Fi access points. A device monitoring service can communicate with internal and/or external mapping API's to render a device monitoring user interface comprising a visual representation of the location of the tracking device.

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PRINTED TAG REAL-TIME TRACKING

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of and priority to co-pending U.S. Application entitled “Printed Tag Real-Time Tracking” having serial no. 13/799,272 filed March 13, 2013, the entirety of which is hereby incorporated by reference.

BACKGROUND

[0002] Tracking devices are used today to monitor the location of people or things in real-time. Yet, tracking devices remain relatively costly, add notable weight to devices in which they are implemented, and/or take up valuable space in devices in which they are implemented. Interfacing with user-friendly frameworks for the provision of tracking device locations to an end-user remains burdensome. Moreover, integrated traceability in indoor as well as outdoor situations remains problematic.

SUMMARY

[0003] Disclosed herein are various embodiments of tracking devices and systems and methods for monitoring tracking devices capable of seamless indoor and outdoor tracking transitions. In an aspect, one or more tracking devices can comprise, for example, printable circuitry and antennas combined with one or more receivers/transceivers on a substrate. The tracking devices can be configured, for example, to localize the tracking device via GPS or an alternative localization strategy based on a determination of whether GPS communication is available. A modified RSSI fingerprinting methodology can be

used to accurately determine a location of the tracking devices using Wi-Fi access points. A device monitoring service can communicate with internal and/or external mapping API's to render a device monitoring user interface comprising a visual representation of the location of one or more of the tracking devices.

[0004] A system is also provided to monitor one or more tracking devices, such as but not limited to the tracking devices disclosed herein. In one or more aspects, the system can comprise: at least one computing device in communication with at least one tracking device, the at least one tracking device comprising: a printed circuit on a substrate comprising a localization system and a communication system, the localization system configured to obtain location data to localize the tracking device via a global positioning system (GPS), the communication system configured to obtain the location data to localize the tracking device via an alternative localization strategy responsive to the localization system being unable to obtain the location data via GPS, the localization system and the communication system configured to communicate via an antenna; and at least one application executable in the at least one computing device, the application comprising: logic that determines a location of the tracking device based at least in part on the location data; logic that encodes the location of the tracking device in a user interface; and logic that transmits the user to a client device for rendering.

[0005] In various aspects, the application can further comprise: logic that communicates with a mapping application programming interface (API) to generate a map comprising the location of the tracking device; and logic that encodes the map comprising the location of the tracking device in the user interface. The application can include logic that transmits the location data to the client device to be rendered in a mapping application on the client device. The logic that determines the location of the tracking device based at least in part on the location data further comprises can include: logic that determines at least three estimated locations of the tracking device against at least three access points; and logic that determines a final location of the tracking device based at least in part on the three estimated locations.

[0006] A method is also provided for monitoring one or more tracking devices, such as but not limited to those disclosed herein. In one or more aspects, the method can comprise the steps of: receiving, in a computing device, location data from a tracking device, the tracking device comprising: a printed circuit on a substrate in communication with a localization system and a communication system, the localization system configured to obtain the location data to localize the tracking device via a global positioning system (GPS), the communication system configured to obtain the location data via an alternative localization strategy responsive the localization system being unable obtain the location data via GPS, the localization system and the communication system configured to communicate via an antenna; determining, in the computing device, a location of the tracking device based at least in part on the location data; rendering the location of the tracking device in a user interface; and transmitting the user interface to a client device for rendering.

[0007] In various aspects, the method can further comprise the steps of: communicating, in the computing device, with a mapping application programming interface (SPI) to generate a map comprising the location of the tracking device; and encoding, in the computing device, the map comprising the location of the tracking device in the user interface. The method can include the step of transmitting the location data to the client device to be rendered in a mapping application on the client device. The step of determining in the computing device, the location of the tracking device based at least in part on the location data can comprise: determining at least three estimated locations of the tracking device against at least three access points; and determining a final location of the tracking device based at least in part on the three estimated locations.

[0008] In various aspects in the system or the method or both Wi-Fi, Bluetooth, Radiofrequency (RF), Ultrasonic, Z-Wave, and/or ZigBee can be used as the alternative localization strategy to obtain the location data. The location data can be measured for example, via received signal strength indication (RSSI), time of arrival (TOA), Angle of Arrival (AOA), time difference of arrival (TDOA), or up-link time difference of arrival (U-TDOA). The antenna can be a printed antenna on a substrate, for example a paper substrate, the printed antenna comprising an L-shaped absence in a rectangular monopole structure.

[0009] In various aspects, in the system or the method or both the printed circuit can comprise nanoparticle ink printed on a substrate. The substrate can be, for example, paper or plastic.

[0010] Other devices, systems, methods, features, and advantages of the present disclosure for printed tag real-time tracking will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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.

[0012] FIGS. 1A-B are drawings of individual components that can be employed in creating a tracking device.

[0013] FIG. 2 is a drawing of the individual components of FIGS. 1A-B that can be combined as layered components to create a tracking device.

[0014] FIG. 3 is a schematic block diagram of an exemplary tracking device according to various embodiments of the present disclosure.

[0015] FIG. 4 is a drawing of a networked environment in communication with the tracking device of FIG. 3 according to various embodiments of the present disclosure.

[0016] FIG. 5 is a drawing of an example of a user interface rendered by a client in the networked environment of FIG. 4 according to various embodiments of the present disclosure.

[0017] FIG. 6 is a flowchart illustrating one example of functionality implemented as portions of the tracking device executed in a computing environment in the networked environment of FIG. 4 according to various embodiments of the present disclosure.

[0018] FIG. 7 is a flowchart illustrating one example of functionality implemented as portions of a location determination application and/or a device monitoring service executed in a computing environment in the networked environment of FIG. 4 according to various embodiments of the present disclosure.

[0019] FIG. 8 is a schematic block diagram that provides one example illustration of a computing environment employed in the networked environment of FIG. 4 according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

[0020] The present disclosure relates to providing an end-to-end system for providing and/or monitoring tracking devices as well as a tracking device for use in the system. As can be appreciated, tracking devices are used today to monitor the location of people or things in real-time. Yet, tracking devices remain relatively costly, add notable weight to devices in which they are implemented, and/or take up valuable space in devices in which they are implemented. For example, tracking devices can require circuitry that is bulky or burdensome. Damage to the tracking devices requires replacement of the tracking devices which can present an undue expense. Typically, infrastructure capable of interacting with tracking devices require expensive infrastructure placement at relatively proximate intervals. For example, radio-frequency identification (RFID) tracking devices require RFID readers every so many feet. Further, provision of a user-friendly monitoring interface capable of seamless traceability in outdoor as well as indoor environments remains problematic.

[0021] For example, by utilizing printable circuitry the cost of constructing a tracking device can be drastically reduced. Low cost fabrication methods can be used for the tracking devices such as reel-to-reel or roll-to-roll printing. In addition, environment friendly materials can be used.

[0022] Moreover, implementing one or more forms of localization and/or communication can utilize existing infrastructure (*e.g.*, global positioning system (GPS), wireless access points, Bluetooth devices, etc.) while providing redundancy and reliability. Implementing one or more forms of localization and/or communication can also provide tracking across difference environments, such as indoor and outdoor environments. In the following discussion, a general description of the system and its components is provided, followed by a discussion of the method of operation of the same.

[0023] With reference to FIG. 1A, shown are the components of an exemplary tracking device for use in the present system. The tracking device can be printed using, for example, an inkjet printer. In the non-limiting example of FIG. 1A, a printed tracking device can comprise a circuit 103 printed on a substrate 106, one or more antennas 109 printed on a substrate 112, and a battery 115. A substrate 106 for circuitry and/or a substrate 112 for antennas 109 can comprise, for example, paper, plastic, Silicon, polymer, or other material. As can be appreciated, a circuit and/or antenna can be printed using relatively inexpensive inkjet and/or screen printing technology. For example, an inkjet printer can utilize conductive ink to print a complete and/or partial circuit on a substrate, the circuit capable of being combined with additional circuitry. Conductive ink can comprise, for example, ink comprising conductive nanoparticles, nanotubes, and/or other conductive materials such as gold, silver, copper, silicon, and/or any combination thereof. As can be appreciated, various paper and/or plastic substrates can be used to flex and/or bend without damaging the circuit, and can be selected to be environmentally friendly. In the case of an inkjet printer, the thickness of the substrate can be selected for use in the printer.

[0024] In order to power a lightweight, flexible, and minimal tracking device, a battery 115 can comprise, for example, a flexible battery. A flexible battery, for example, can be capable of being folded or bended without compromising the integrity of the battery. Such batteries can be printed using nanotube ink or can be commercially available (*e.g.*, flexible lithium-ion, flexible nickel-cadmium batteries, *etc.*). When combined with flexible circuitry, the combination of the circuitry 103 and the battery 115 can also be capable of being folded or bended without compromising the integrity of a tracking device. Alternatively, a tracking device can comprise any other power source in lieu of a battery 115. Additionally, a battery 115 can be combined with various recharging circuitry (not shown). Recharging circuitry, for example, can comprise a solar panel, perpetual motion recharging circuitry, and/or other recharging circuitry.

[0025] With reference to FIG. 1B, shown is an exemplary antenna 109 of FIG. 1A that can be deployed in a tracking device. As discussed above with respect to FIG. 1A, an antenna 109 can be created by printing the antenna 109 using an inkjet printer, screen printing, and/or any like method. Moreover, the antenna 109 can be printed on a substrate 112 that can comprise, for example, paper, plastic, Silicon, and/or any other material also as discussed above. The antenna 109 can be printed to be right-hand circularly polarized (CP). CP can be achieved by exciting two orthogonal field components with equal magnitude and a 90 degree phase difference. In the non-limiting example of FIG. 1B, the two orthogonal field components are excited via asymmetry or a perturbation in the antenna structure. For example, an L-shaped absence 118 is introduced in the rectangular monopole structure 121 to achieve circular polarization.

[0026] With reference to FIG. 2, shown are the layers of an exemplary tracking device 203 created using the components of FIGS. 1A-B. In the non-limiting example of FIG. 2, a tracking device 203 can comprise a circuit 103 printed on a substrate 106, one or more antennas 109 printed on a substrate 112, and a battery 115. In one embodiment, the circuit 103 printed on a substrate 106 can be combined with one or more localization and/or communications systems, wherein a system can comprise, for example, receivers, transmitters, transceivers, and/or other localization and/or communication circuitry. For example, the circuit 103 can be combined with receiver 206 and receiver 209 to configure the tracking device 203 to localize and/or communicate via GPS, Wi-Fi, Radiofrequency (RF), Ultrasonic, Bluetooth, Z-Wave, ZigBee, and/or any other localization and/or communication technology. In certain embodiments, receiver 206 and receiver 209 can represent the same physical circuitry capable of providing communication as well as localization. For instance, a receiver 206 and a receiver 209 can both comprise a Wi-Fi transceiver. By using paper substrates, a circuit 103 can be combined with one or more antennas 109 and a battery 115 to create a durable and lightweight tracking device 203 capable of inexpensive reproduction. The layers of the individual components of the tracking device 203 of FIG. 2 can be combined to form a uniform tracking device 203.

[0027] With reference to FIG. 3, shown is an exemplary circuit block diagram for a tracking device 203. A tracking device 203, for example, can comprise a battery 115 (or alternative power source), antennas 109, a microcontroller 303, and a Subscriber Identity Module (SIM) connector 306. As discussed above with respect to FIGS. 1 and 2, a battery 115 can include a flexible battery ensuring the tracking device 203 is capable of being bent or folded. Antennas 109 are configured to provide the tracking device 203 and its components with localization and/or communication. A SIM connector 306 is configured to facilitate the addition of portable electronics or other circuitry to the tracking device 203. As a non-limiting example, a SIM card can be used permitting a mobile communications system to identify the tracking device 203 based on the data residing within the SIM card (*e.g.*, a unique tracking device identifier). A microcontroller 303 can be configured to coordinate among the components of the tracking device 203, as can be appreciated.

[0028] Moreover, a tracking device 203 can comprise one or more receivers/transceivers capable of localization and/or communication via one or more forms of communication. In the non-limiting example of FIG. 3, a tracking device 203 can comprise a GPS receiver 309 and Wi-Fi transceiver 312. As will be discussed in greater detail below, a Wi-Fi transceiver 312 can be used to localize the tracking device 203 in the event GPS is unavailable to do so (*e.g.*,, the tracking device 203 is unable to receive a signal from a GPS system or an acquired signal fails to resolve to an acceptable fix). Although shown utilizing a Wi-Fi transceiver 312 and a GPS receiver 309, other receivers and/or transceivers can be utilized permitting the tracking device 203 to localize via alternative localization strategies using technologies such as RF, Ultrasonic, Z-wave, ZigBee, Bluetooth, and/or any other form of localization and/or communication. The tracking device 203 can thus communicate with the present tracking system across multiple, differing environments, such as indoor and outdoor environments.

[0029] With reference to FIG. 4, shown is a networked environment 400 according to various embodiments. The networked environment 400 includes a computing environment 403, a client device 406, and/or access points 408, which are in data communication with each other via a network 409. The network 409 includes, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, or other suitable networks, *etc.*, or any combination of two or more such networks. Access points 408 can include, for example, wireless access points 408 that can be used to facilitate communication between a tracking device 203 and the network 409. Alternatively, access points 408 can comprise one or more cell sites that facilitate the communication of the tracking device 203 over one or more cellular networks. Such cellular networks can be capable of communicating, for example, via Code Division Multiple Access (CMDA), Global System for Mobile Communications (GSM), and/or any variation thereof. Utilizing a GSM network, general packet radio service (GPRS) services can be used for communication between the access points 408 and the one or more tracking devices 203. In various embodiments, a tracking device 203 can be capable of communication directly with the network 409 without access points 408 and/or computing environment 403 and/or client device 406, as can be appreciated.

[0030] The computing environment 403 can comprise, for example, a server computer or any other system providing computing capability. Alternatively, the computing environment 403 can employ a plurality of computing devices that can be employed that are arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices can be located in a single installation or can be distributed among many different geographical locations. For example, the computing environment 403 can include a plurality of computing devices that together can comprise a cloud computing resource, a grid computing resource, and/or any other distributed computing arrangement. In some cases, the computing environment 403 can correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources can vary over time.

[0031] Various applications and/or other functionality can be executed in the computing environment 403 according to various embodiments. Also, various data is stored in a data store 412 that is accessible to the computing environment 403. The data store 412 can be representative of a plurality of data stores 412 as may be appreciated. The data stored in the data store 412, for example, is associated with the operation of the various applications and/or functional entities described below.

[0032] The components executed on the computing environment 403, for example, include a location determination application 415, a device monitoring service 418, and other applications, services, processes, systems, engines, or functionality not discussed in detail herein.

[0033] The location determination application 415 is executed to determine the location of one or more tracking devices 203, as will be discussed in greater detail below. For example, location data 421 can be received from one or more tracking devices 203 via any form of communication capable of providing location data 421 associated with the one or more tracking devices 203. The location of the one or more tracking devices 203 can be determined based at least in part on the location data 421 provided by the tracking device 203.

[0034] The device monitoring service 418 is executed to provide an interface thereby permitting a user to monitor one or more tracking devices 203. For example, the device monitoring service 418 can obtain location data 421 from the location determination application 415. Subsequently, the location data 421 can be transmitted by the device monitoring service 418 to one or more mapping application programming interfaces (API). In response, a digital map comprising one or more indicators (*e.g.*, an icon) identifying the location of one or more tracking devices 203 on the digital map can be received by the device monitoring service 418. This map can be encoded in a user interface 472 (*e.g.*, a network page, a mobile application page, *etc.*) and transmitted to a client 406 (FIG. 4) for rendering.

[0035] The device monitoring service 418 can be further executed to authenticate a user (*i.e.*, requiring a user to provide a user name, password, biometric data, *etc.*) prior to presenting and/or transmitting information associated with the tracking devices 203. As a result, only information pertaining to tracking devices 203 associated with an account or user ID 436 can be presented to that user.

[0036] The data stored in the data store 412 includes, for example, location data 421, network data 424, Wi-Fi data 427, GPS data 430, device identifier (ID) 433, user ID 436, radio maps 439, and potentially other data. Location data 421 can comprise, for example, data obtained from one or more tracking devices 203 that can be related to and/or can be used in determining the location of the one or more tracking devices 203. Moreover, location data 421 can comprise a position database of all tracking devices 203, whether functional or non-functional. Network data 424 can be information related to frames and/or packets of information transferred over network 409. Wi-Fi data 427 can comprise information associated with utilizing wireless access points 408 to determine a location of a tracking device 203. GPS data 430 can comprise information obtained by a tracking device 203 configured to localize via GPS. A device ID 433 can be, for example, a unique identifier used to identify a tracking device 203 and/or a group of tracking devices 203. A radio map 439 can comprise, for example, an RF signature map and/or an RF signature map history. A radio map 439 can further comprise associations to points in a digital map.

[0037] The client 406 is representative of a plurality of client devices that can be coupled to the network 409. The client 406 can comprise, for example, a processor-based system such as a computer system. Such a computer system can 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 client 406 can include a display 466. The display 466 can 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, LCD projectors, or other types of display devices, *etc.*

[0038] The client 406 can be configured to execute various applications such as a client application 469 and/or other applications. The client application 469 can be executed in a client 406, for example, to access network content served up by the computing device 403 and/or other servers, thereby rendering a user interface 472 on the display 466. To this end, the client application 469 can comprise, for example, a browser, a dedicated application, *etc.*, and the user interface 472 can comprise a network page, an application screen, *etc.* The client 406 can be configured to execute applications beyond the client application 469 such as, for example, email applications, social networking applications, word processors, spreadsheets, and/or other applications.

[0039] The tracking device 203 is representative of a plurality of tracking devices 203 that can be coupled to the network 409 or can localize and/or communicate through network 409 via access points 408. Moreover, a tracking device 203 can be configured to receive signals comprising location data 421 and/or other communication data from GPS 483. The tracking device 203 can comprise, for example, the components of FIG. 2 to communicate with network 409 via Wi-Fi, Ultrasonic, Infared, RF, Bluetooth, Z-wave, ZigBee, and/or any wireless communication technology. These components can include one or more receivers 486, transceivers, transmitters, and/or other communication circuitry. Alternatively, a tracking device 203 can comprise one or more of a commercially available tracking device 203, as can be appreciated.

[0040] An access point 408 can be configured to receive communication from one or more tracking devices 203, translate the communication received into a form of communication (*e.g.*, data packets) capable of being communicated over network 409, and transmit the communication to, for example, computing device 403 and/or client 406. Furthermore, a tracking device 203 can comprise an identifier 489 which can be communicated through network 409 in order to identify the tracking device 203, as can be appreciated. For example, an identifier 489 can be unique to a tracking device 203.

[0041] Next, a general description of the method of operation of the various components of the networked environment 400 is provided. To begin, the location determination application 415 can determine the location of one or more tracking devices 203. For example, location data 421 can be received from one or more tracking devices 203. Location data 421 can be obtained via GPS or any alternative form of wireless communication such as Wi-Fi. If the location data 421 was obtained through a GPS receiver, location data 421 can comprise, for example, data that can be processed in order to determine a location of the tracking device 203. Alternatively, in the event localization through GPS was unable to be established by a tracking device 203, a tracking device 203 can have obtained location data 421 from one or more wireless access points 408. The location data 421 can be transmitted by the tracking device 203 to the computing device 403 over network 409 by utilizing the access points 408, or like devices. Accordingly, the location data 421 received from the tracking device 203 can be used in the determination of a location of the tracking device 203. The location determined can be based at least in part on the location data 421 provided by the tracking device 203. In addition, other data can be used in determining the location such as radio maps 439, *etc.*

[0042] For example, location data 421 can have been obtained via a Wi-Fi receiver embedded in a tracking device 203. In this non-limiting example, Received Signal Strength Indicator (RSSI) methodologies can be used in determining the location of the tracking device 203 by measuring the power of a received signal, usually measured in decibels (dB) of the measured power referenced against one milliwatt (mW). Such RSSI methodologies can include RSSI triangulation and/or RSSI fingerprinting. RSSI triangulation can comprise triangulating a location of a tracking device 203 using omnidirectional access points 408 in order to determine coordinates of a transceiver embedded within the tracking device 203.

[0043] In RSSI fingerprinting, one or more radio maps 439 can be used to compare geo-reference RSSI measurements (*i.e.*, fingerprints) from one or more access points 408, or from the tracking device 203 itself, during an "online phase". The RSSI measurements can be compared to one or more radio maps 439 to estimate a location of the tracking device 203 based at least in part on the RSSI measurements. A probability distribution function can be applied to determine the highest probability location of the tracking device 203. During an "offline phase" RSSI measurements can be used to create radio maps 439, although radio maps 439 can be manually created using alternative technology (*e.g.*, radar, sonar, *etc.*).

[0044] RSSI fingerprinting traditionally observes RSSI measurements of a tracking device 203 measured against three or more access points 408. A final location can be determined by applying Gaussian mixture models, Markov models, hidden Markov models, *etc.* against a radio map 439 to determine *one* location of the tracking device 203 with the highest probability. However, *three or more* locations of the tracking device 203 can be observed against the three or more access points 408. The three or more locations can be fused to determine a final location utilizing, for example, a Euclidean, Rule based, GMM, Markov models, hidden Markov models, *etc.*, classification algorithm.

[0045] Although described in an embodiment specific to Wi-Fi based access points 408, alternative technologies can be used to conduct RSSI fingerprinting. Such technologies that can utilize RSSI fingerprinting can include GSM, CDMA, Bluetooth, Z-Wave, ZigBee, RF, Ultrasonic, *etc.* Similarly, although described with respect to RSSI other measurements can be utilized in place of or in combination with RSSI in determining a fingerprint of a tracking device 203 such as time of arrival (TOA), angle of arrival (AOA), time difference of arrival (TDOA), uplink-time difference of arrival (U-TDOA), and/or any combination thereof.

[0046] Upon determining the location of one or more tracking devices 203, the location determination application 415 can store the location data 421, and/or the location itself, in data store 412 in association with a tracking device 203 or its identifier 489. Accordingly, the location data 421 can be used in determining the location of a tracking device 203 over time, paths traveled, places visited, length of time in a location, *etc.*

[0047] The device monitoring service 418 is executed to provide an interface thereby permitting a user to monitor one or more tracking devices 203. For example, the device monitoring service 418 can obtain location data 421 from the location determination application 415. Subsequently, the location data 421 can be transmitted by the device monitoring service 418 to a mapping API such as Google® Maps, Bing® Maps, Yahoo!® Maps, AOL® MapQuest, and/or any other mapping API. In response, a map comprising an indicator (*e.g.*, an icon) identifying the location of tracking device 203 on a map can be received by the device monitoring service 418. This map can be encoded in a user interface 472 (*e.g.*, a network page, a mobile application page, *etc.*) and transmitted to a client 406 (FIG. 4) for rendering. The user interface 472 can comprise additional information about the tracking devices 203 such as geocoded addresses, duration at a location, routes traveled, and/or any other information about the tracking devices 203.

[0048] The device monitoring service 418 can require authentication from a user (*i.e.*, requiring a user to provide a user name, password, biometric data, *etc.*) prior to presenting and/or transmitting information associated with the tracking devices 203. Accordingly, a unique user account or user ID 436, used during authentication, can be associated with one or more tracking devices 203. As a result, only information pertaining to tracking devices 203 associated with an account or user ID 436 can be presented to that user.

[0049] Referring next to FIG. 5, shown is an exemplary embodiment of a user interface 472 rendered in a client application 469, for example, on a client 406 (not shown). In the non-limiting example of FIG. 5, the device monitoring service 418 (FIG. 4) can render a user interface 472, embodied in FIG. 5 as a network page, comprising a digital map 503. As discussed above with respect to FIG. 4, determined locations of tracking devices 203 (not shown) can be transmitted to one or more mapping services by communicating, for example, through the mapping service's API. In return, the mapping service provides the device monitoring service 418 a digital map 503 comprising the determined locations that can be identified with an icon. The device monitoring service 418 can encode the digital map 503 in a network page to be transmitted to a client 406 for rendering. Additionally, the digital map 503 can be updated in real-time by making subsequent calls to the one or more mapping services upon a request by a user or upon the occurrence of a predefined condition. For example, the digital map 503 can be updated and/or re-rendered upon a predefined delay and/or upon noticeable movement of a tracking device 203.

[0050] Moreover, information associated with the tracking devices 203 can be encoded in the user interface 472. For example, an address 506 of each tracking device 203 can be determined utilizing geocoding or like technique. Additionally, statistics associated with the location of the tracking device 203 also can be determined and encoded in the network page. For example, a time in a location metric 509 can be encoded in the network page to show a length of time a tracking device 203 has remained in a particular position or range of positions.

[0051] As can be appreciated, the device monitoring service 418 can require authentication (*i.e.*, requiring a user to provide a user name, password, biometric data, *etc.*) before presenting and/or transmitting information associated with the tracking devices 203. Accordingly, a user account or user ID 436 (FIG. 4), used during authentication, can be associated with one or more tracking devices 203. As a result, only information pertaining to tracking devices 203 associated with an account or user ID 436 can be presented.

[0052] Turning now to FIG. 6, shown is a flowchart that provides one example of the operation of a portion of the tracking device 203 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 can be employed to implement the operation of the tracking device 203 as described herein. As an alternative, the flowchart of FIG. 6 can be viewed as depicting an example of steps of a method implemented in the computing environment 403 (FIG. 4) according to one or more embodiments.

[0053] Beginning with box 603, a determination is made whether the tracking device 203 is able to localize via GPS. For example, a GPS receiver embedded in the tracking device 203 can attempt to receive one or more signals from one or more satellites. When indoors or in congested areas or in other similar environments, GPS signals can be inhibited. Thus, the GPS receiver embedded in the tracking device 203 can be unable to receive signals from any GPS satellite. If a tracking device 203 via its GPS receiver is able to localize (*e.g.*, obtain location data 421 via a signal) from a GPS satellite, in box 606, GPS can be used in obtaining location data 421. When using a GPS receiver, location data 421 can comprise, for example, data from the signal obtained from one or more GPS satellites as well as data used in computing a location of the tracking device 203.

[0054] Alternatively, if a tracking device 203 is unable to localize via GPS, in box 609, an alternative localization strategy can be attempted to obtain location data. An alternative localization strategy can comprise, for example, using Wi-Fi, RF, Ultrasonic, Bluetooth, Z-Wave, ZigBee, or any other technology to localize the tracking device 203. In one embodiment, Wi-Fi can be used in order to obtain location data 421. One or more receivers can be embedded in a tracking device 203 capable of communicating via one or more of these technologies, as can be appreciated. For example, a Wi-Fi receiver embedded on the tracking device 203 can attempt communication with one or more Wi-Fi wireless access points 408. As can be appreciated, other receivers can be embedded in the event a GPS signal or Wi-Fi signal is unable to be obtained and/or communication established.

[0055] By localizing via Wi-Fi (or any alternative form of localization) in the event GPS is unavailable, a tracking device 203 can be capable of a seamless transition for outdoor to indoor tracking and vice versa. Ultimately, in box 612, the location data 421 obtained via GPS (box 606) or the alternative localization strategy (box 609) can be transmitted to, for example, a computing device 403 (FIG. 4). The location data 421 can be processed in the computing device 403 to determine a location of the tracking device 203, as will be discussed in greater detail below.

[0056] Moving on to FIG. 7, shown is a flowchart that provides one example of the operation of a portion of the location determination application 415 and/or the device monitoring service 418 according to various embodiments. It is understood that the flowchart of FIG. 7 provides merely an example of the many different types of functional arrangements that can be employed to implement the operation of the portion of the location determination application 415 and/or the device monitoring service 418 as described herein. As an alternative, the flowchart of FIG. 7 can be viewed as depicting an example of steps of a method implemented in the computing environment 400 (FIG. 4) according to one or more embodiments.

[0057] Beginning with box 703, location data 421 can be received from one or more tracking devices 203. As discussed above with respect to FIG. 6, location data 421 can be obtained via GPS or any alternative form of localization. If the location data 421 was obtained through a GPS receiver, location data 421 can comprise, for example, data that can be processed in order to determine a location of the tracking device 203. Alternatively, in the event localization through GPS was unable to be established by a tracking device 203, a tracking device 203 can have obtained location data 421 from one or more wireless access points. The location data 421 can be transmitted by the tracking device 203 to a computing device 403 (FIG. 4) over network 409 (FIG. 4) by utilizing the wireless access points 408, or like devices.

[0058] In box 706, the location data 421 received from the tracking device 203 can be used in the determination of a location of the tracking device 203. The location determined can be based at least in part on the location data 421 provided by the tracking device 203. In addition, other data can be used in determining the location such as radio maps 439 (FIG. 4), *etc.*

[0059] For example, location data 421 can have been obtained via a Wi-Fi receiver embedded in a tracking device 203. In one embodiment, Received Signal Strength Indicator (RSSI) methodologies can be used in determining the location of the tracking device 203 by measuring the power of a received signal. The RSSI methodologies can include RSSI triangulation and/or RSSI fingerprinting. As discussed above with respect to FIG. 4, *three or more* locations of the tracking device 203 can be observed against three or more access points 408. The three or more locations can be fused to determine a final location utilizing GMM, Morkov models, *etc.* rather than the traditional RSSI fingerprinting approach.

[0060] Next, in box 709, the location data 421, and/or the location itself, can be stored in data store 412 (FIG. 4) in association with a tracking device 203 or its identifier 489 (FIG. 4). Accordingly, the location data 421 can be used in determining the location of a tracking device 203 over time, paths traveled, places visited, *etc.*

[0061] In box 712, the location data 421 can be transmitted to a mapping API such as Google® Maps, Bing® Maps, Yahoo!® Maps, AOL® MapQuest, and/or any other mapping API. As can be appreciated, the location determined in box 706 of a tracking device 203 (or many locations of many tracking devices 203), can be transmitted to the mapping API. In response, a map such as a digital map comprising an indicator (*e.g.*, an icon) identifying the location of tracking device 203 on a map can be received, in box 715. In box 718, this map can be encoded in a user interface (e.g., a network page, a mobile application page, etc.). Finally, in box 721, the user interface 472 can be transmitted to a client 406 (FIG. 4) for rendering.

[0062] With reference to FIG. 8, shown is a schematic block diagram of the computing environment 403 according to an embodiment of the present disclosure. The computing environment 403 includes one or more computing devices 403. Each computing device 403 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. To this end, each computing device 403 can comprise, for example, at least one server computer or like device. The local interface 809 can comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

[0063] 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 a location determination application 415, a device monitoring service 418, and potentially other applications. Also stored in the memory 806 can be a data store 412 and other data. In addition, an operating system can be stored in the memory 806 and executable by the processor 803.

[0064] It is understood that there can be other applications that are stored in the memory 806 and are executable by the processor 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 can be employed such as, for example, C, C++, C#, Objective C, Java®, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Flash®, or other programming languages.

[0065] A number of software components are stored in the memory 806 and are executable by the processor 803. In this respect, the term "executable" means a program file that is in a form that can ultimately be run by the processor 803. Examples of executable programs can 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 806 and run by the processor 803, source code that can be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory 806 and executed by the processor 803, or source code that can be interpreted by another executable program to generate instructions in a random access portion of the memory 806 to be executed by the processor 803, *etc.* An executable program can be stored in any portion or component of the memory 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.

[0066] The memory 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 806 can 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 can 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 can 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.

[0067] Also, the processor 803 can represent multiple processors 803 and/or multiple processor cores and the memory 806 can represent multiple memories 806 that operate in parallel processing circuits, respectively. In such a case, the local interface 809 can be an appropriate network that facilitates communication between any two of the multiple processors 803, between any processor 803 and any of the memories 806, or between any two of the memories 806, *etc.* The local interface 809 can comprise additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor 803 can be of electrical or of some other available construction.

[0068] Although the location determination application 415, the device monitoring service 418, and other various systems described herein can be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same can 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 can 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.

[0069] The flowcharts of FIGS. 6 and 7 show the functionality and operation of an implementation of portions of the tracking device 203, the location determination application 415, and the device monitoring service 418. If embodied in software, each block can represent a module, segment, or portion of code that comprises program instructions to implement the specified logical function(s). The program instructions can 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 803 in a computer system or other system. The machine code can be converted from the source code, *etc.* If embodied in hardware, each block can represent a circuit or a number of interconnected circuits to implement the specified logical function(s).

[0070] Although the flowcharts of FIGS. 6 and 7 show a specific order of execution, it is understood that the order of execution can differ from that which is depicted. For example, the order of execution of two or more blocks can be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIGS. 6 and 7 can be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the blocks shown in FIGS. 6 and 7 can 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.

[0071] Also, any logic or application described herein, including the location determination application 415 and the device monitoring service 418, 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 803 in a computer system or other system. In this sense, the logic can 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.

[0072] 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 can 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 can 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.

[0073] 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 can 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.

CLAIMS

Therefore, the following is claimed:

1. A system, comprising:

at least one computing device in communication with at least one tracking device, the at least one tracking device comprising:

a printed circuit on a substrate comprising a localization system and a communication system, the localization system configured to obtain location data to localize the tracking device via a global positioning system (GPS), the communication system configured to obtain the location data to localize the tracking device via an alternative localization strategy responsive to the localization system being unable to obtain the location data via GPS, the localization system and the communication system configured to communicate via an antenna; and

at least one application executable in the at least one computing device, the application comprising:

logic that determines a location of the tracking device based at least in part on the location data;

logic that encodes the location of the tracking device in a user interface; and

logic that transmits the user to a client device for rendering.

2. The system of claim 1, wherein one of Wi-Fi, Bluetooth, Radiofrequency (RF), Ultrasonic, Z-Wave, or ZigBee is used as the alternative localization strategy to obtain the location data.

3. The system of claim 1 or 2, wherein the location data is measured via received signal strength indication (RSSI), time of arrival (TOA), Angle of Arrival (AOA), time difference of arrival (TDOA), or up-link time difference of arrival (U-TDOA).

4. The system of any of claims 1-3, wherein the antenna further comprises a printed antenna on a substrate, the printed antenna comprising an L-shaped absence in a rectangular monopole structure.

5. The system of any of the foregoing claims, the application further comprising:

logic that communicates with a mapping application programming interface (API) to generate a map comprising the location of the tracking device; and

logic that encodes the map comprising the location of the tracking device in the user interface.

6. The system of any of the foregoing claims, the application further comprising:

logic that transmits the location data to the client device to be rendered in a mapping application on the client device.

7. The system of any of the foregoing claims, wherein the logic that determines the location of the tracking device based at least in part on the location data further comprises:

logic that determines at least three estimated locations of the tracking device against at least three access points; and

logic that determines a final location of the tracking device based at least in part on the three estimated locations.

8. The system of any of the foregoing claims, wherein the printed circuit comprises nanoparticle ink printed on the substrate.

9. The system of any of the foregoing claims, wherein the substrate is paper or plastic or both.

10. A method, comprising the steps of:

receiving, in a computing device, location data from a tracking device, the tracking device comprising:

a printed circuit on a substrate in communication with a localization system and a communication system, the localization system configured to obtain the location data to localize the tracking device via a global positioning system (GPS), the communication system configured to obtain the location data via an alternative localization strategy responsive the localization system being unable obtain the location data via GPS, the localization system and the communication system configured to communicate via an antenna;

determining, in the computing device, a location of the tracking device based at least in part on the location data;

rendering the location of the tracking device in a user interface; and

transmitting the user interface to a client device for rendering.

11. The method of claim 10, wherein one of Wi-Fi, Bluetooth, Radiofrequency (RF), Ultrasonic, Z-wave, or ZigBee is used as the alternative localization strategy to obtain the location data.

12. The method of claim 10 or 11, wherein the location data is measured via received signal strength indication (RSSI), time of arrival (TOA), Angle of Arrival (AOA), time difference of arrival (TDOA), or up-link time difference of arrival (U-TDOA).

13. The method of any of claims 10-12, wherein the antenna further comprises a printed antenna on a substrate, the printed antenna comprising an L-shaped absence in a rectangular monopole structure.

14. The method of any of claims 10-13, further comprising the steps of:

communicating, in the computing device, with a mapping application programming interface (API) to generate a map comprising the location of the tracking device; and

encoding, in the computing device, the map comprising the location of the tracking device in the user interface.

15. The method of any of claims 10-14, further comprising:

transmitting the location data to the client device to be rendered in a mapping application on the client device.

16. The method of any of claims 10-15, wherein determining, in the computing device, the location of the tracking device based at least in part on the location data further comprises:

determining at least three estimated locations of the tracking device against at least three access points; and

determining a final location of the tracking device based at least in part on the three estimated locations.

17. The method of any of claims 10-16, wherein the printed circuit comprises nanoparticle ink printed on the substrate.

18. The method of any of claims 10-17, wherein the substrate is paper, or plastic or both.

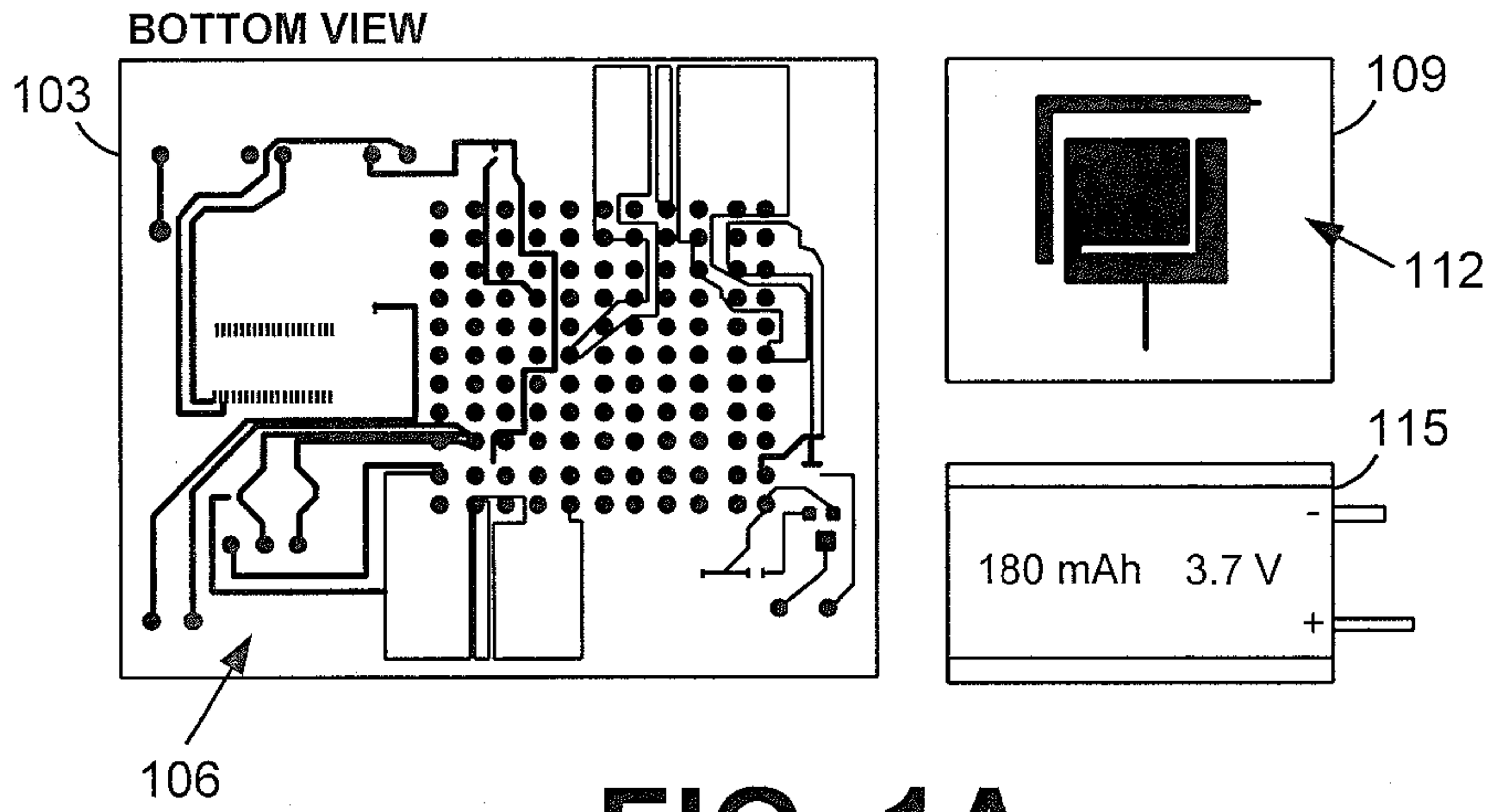

FIG. 1A

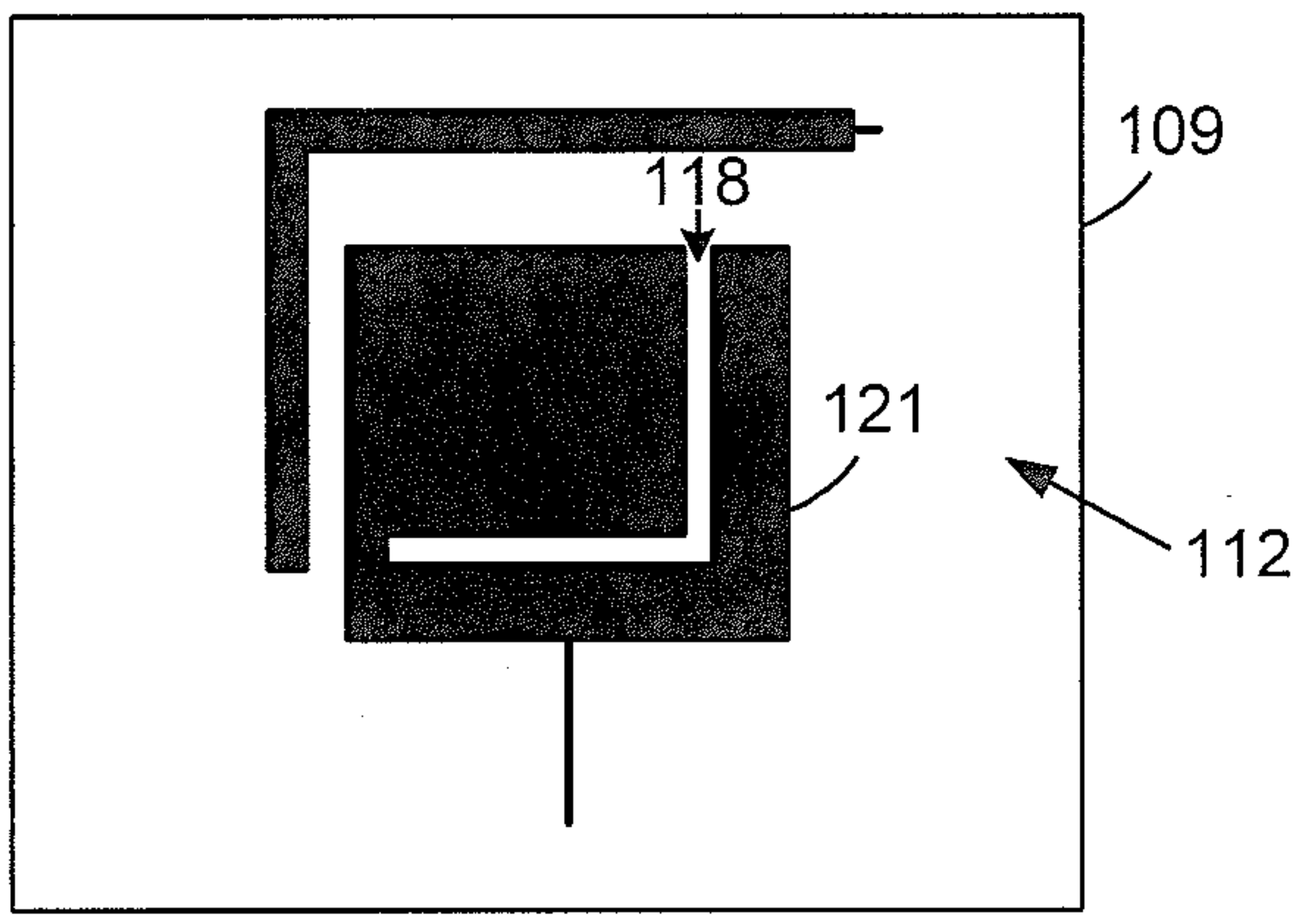

FIG. 1B

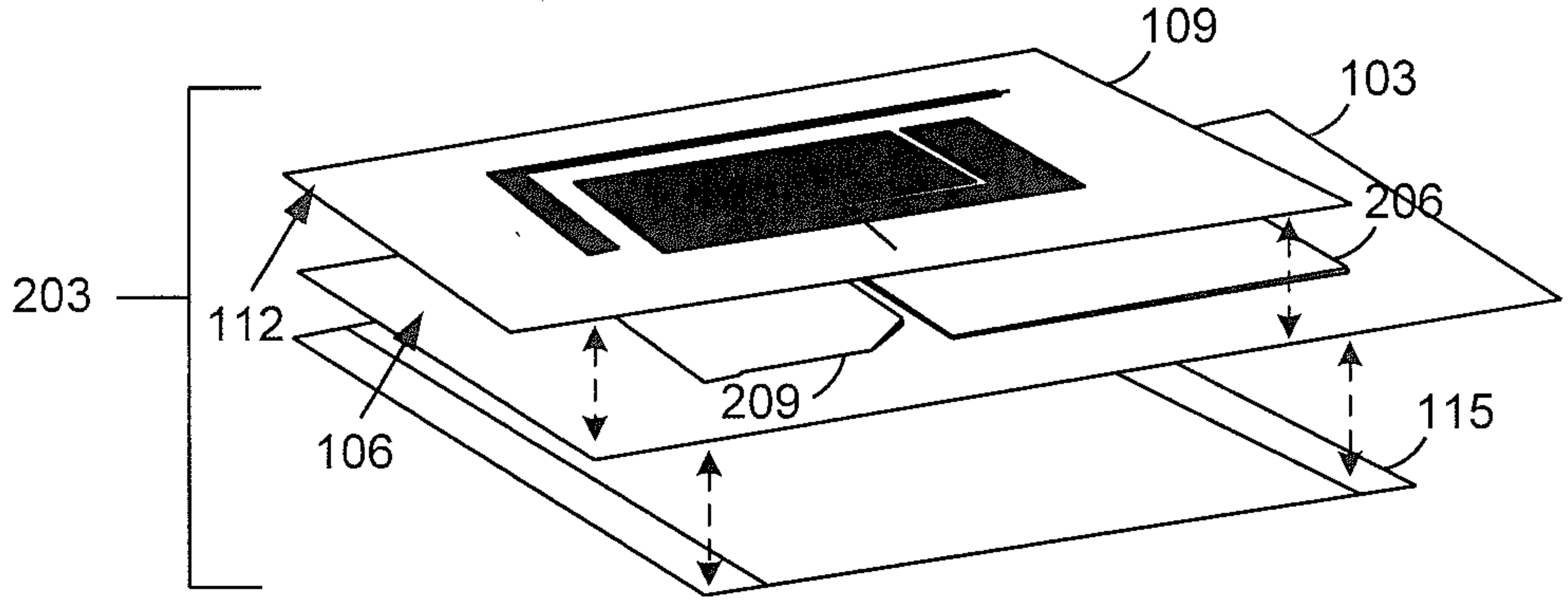
109
103
206
203
112
209
115
106

FIG. 2

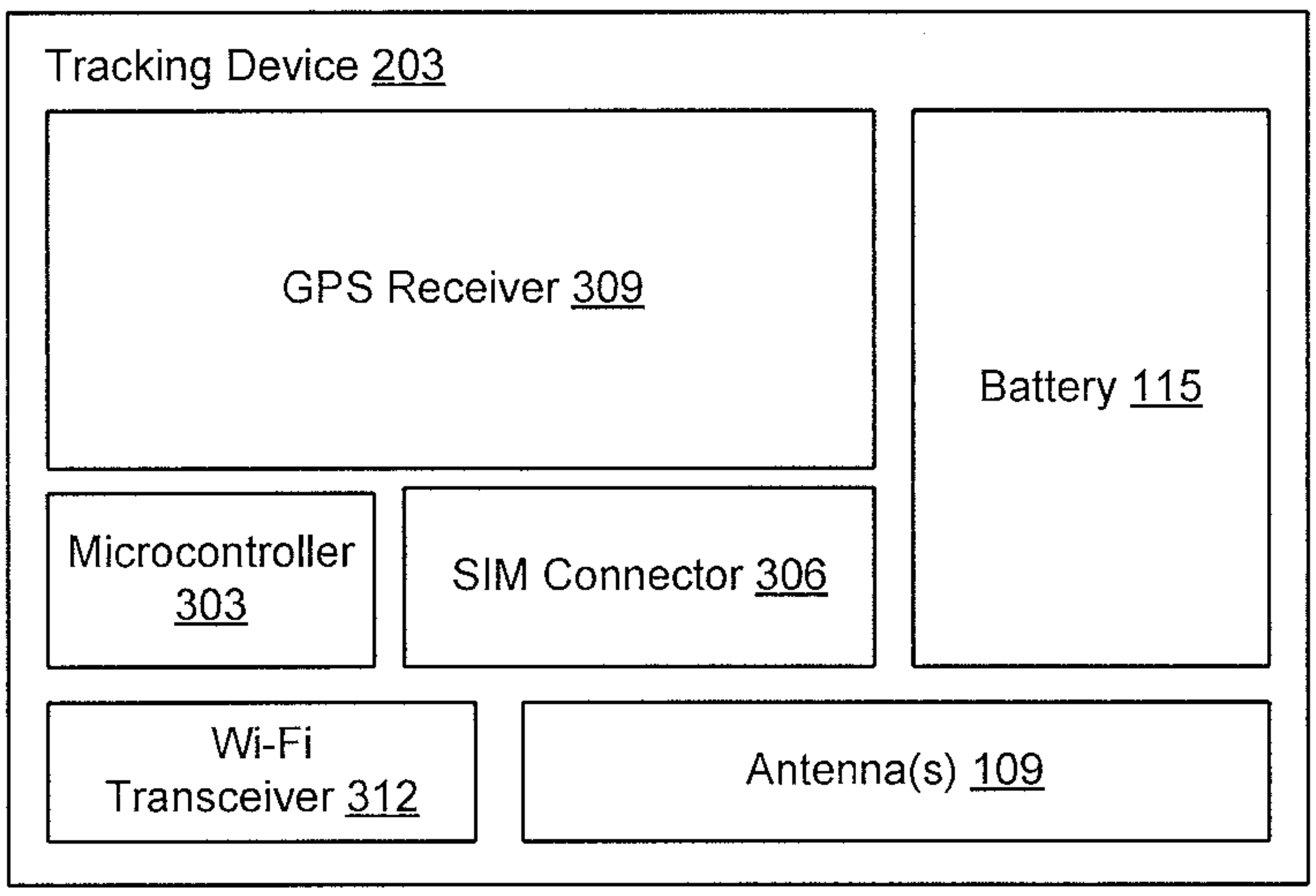
Tracking Device 203
GPS Receiver 309
Battery 115
Microcontroller 303
SIM Connector 306
Wi-Fi Transceiver 312
Antenna(s) 109

FIG. 3

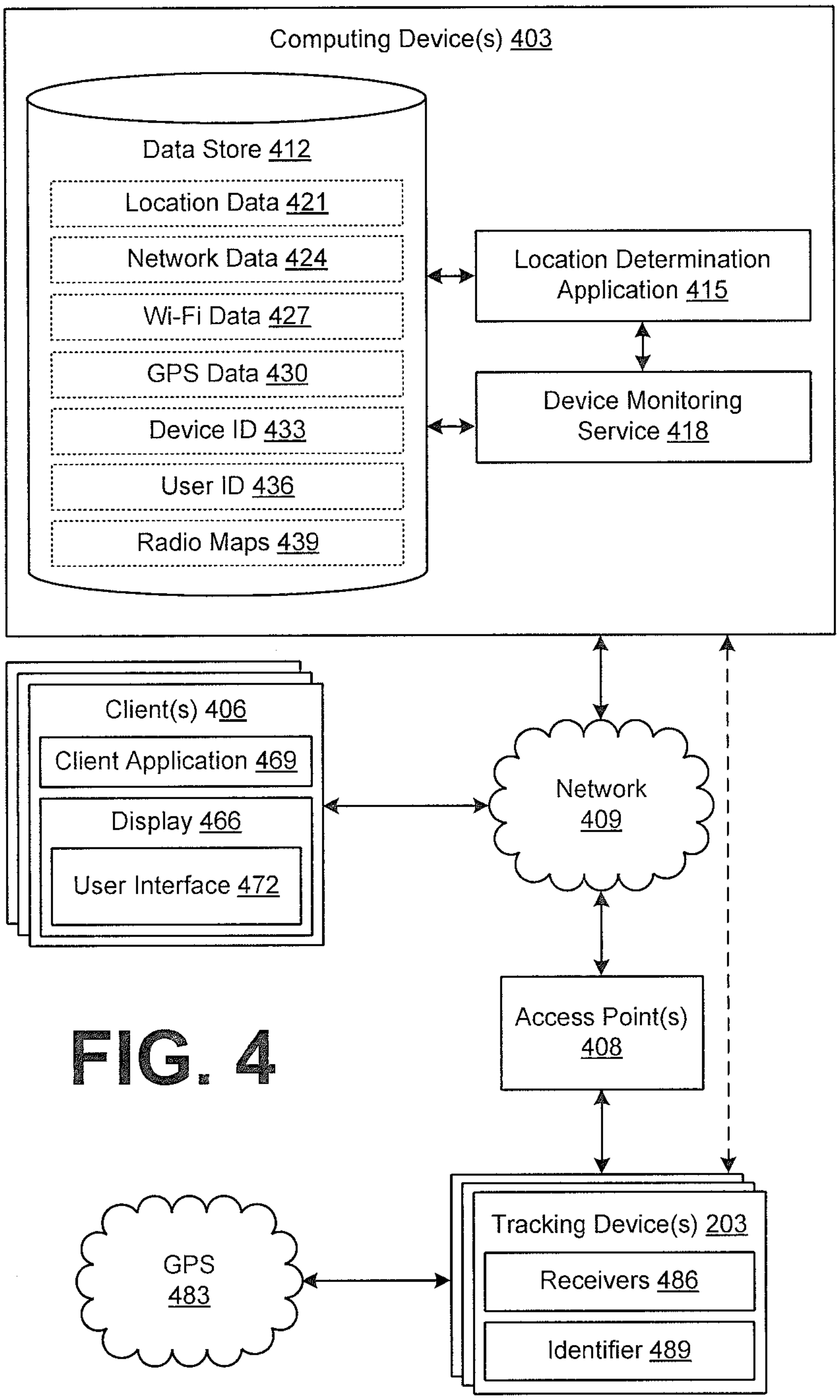
Computing Device(s) 403
Data Store 412
Location Data 421
Network Data 424
Wi-Fi Data 427
GPS Data 430
Device ID 433
User ID 436
Radio Maps 439
Location Determination Application 415
Device Monitoring Service 418
Client(s) 406
Client Application 469
Display 466
User Interface 472
Network 409
Access Point(s) 408
GPS 483
Tracking Device(s) 203
Receivers 486
Identifier 489

FIG. 4

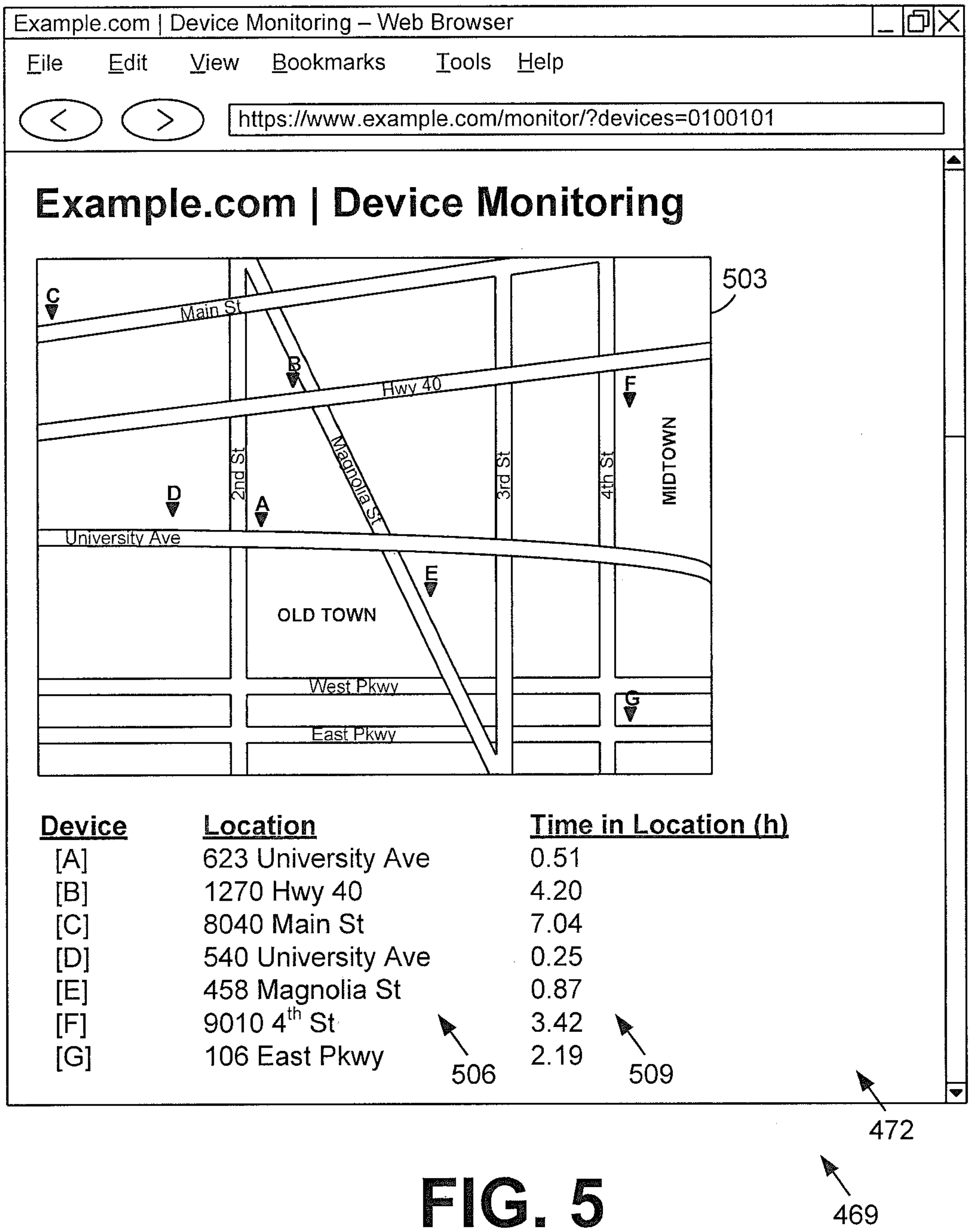
Example.com | Device Monitoring – Web Browser
File Edit View Bookmarks Tools Help
https://www.example.com/monitor/?devices=0100101
Example.com | Device Monitoring
C
Main St
B
Hwy 40
F
MIDTOWN
2nd St
3rd St
4th St
Magnolia St
D
A
University Ave
E
OLD TOWN
West Pkwy
G
East Pkwy
503
Device
Location
Time in Location (h)
[A] 623 University Ave 0.51
[B] 1270 Hwy 40 4.20
[C] 8040 Main St 7.04
[D] 540 University Ave 0.25
[E] 458 Magnolia St 0.87
[F] 9010 4th St 3.42
[G] 106 East Pkwy 2.19
506
509
472
469

FIG. 5

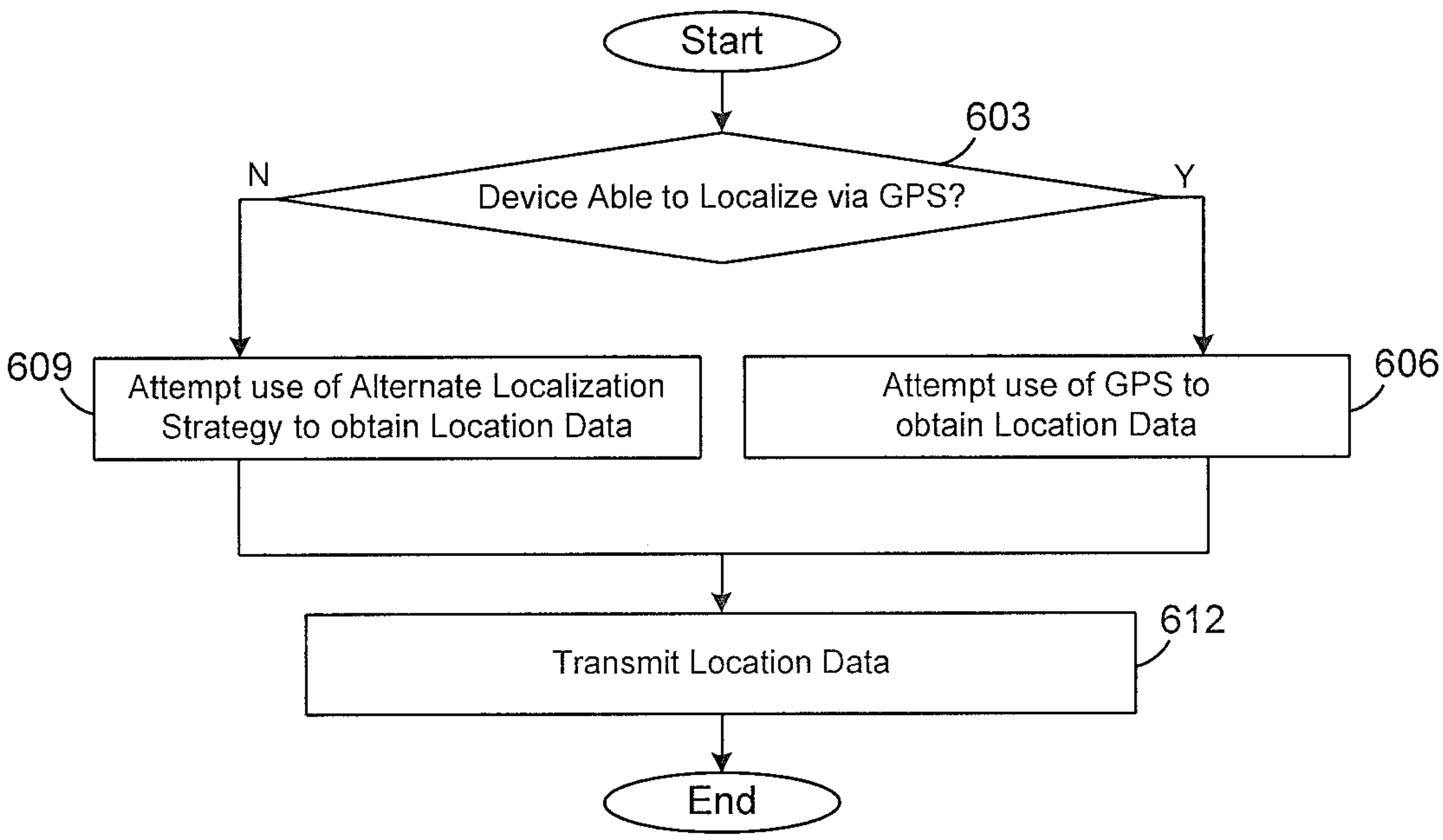
Start
603
N
Device Able to Localize via GPS?
Y
609
Attempt use of Alternate Localization Strategy to obtain Location Data
Attempt use of GPS to obtain Location Data
606
612
Transmit Location Data
End

FIG. 6

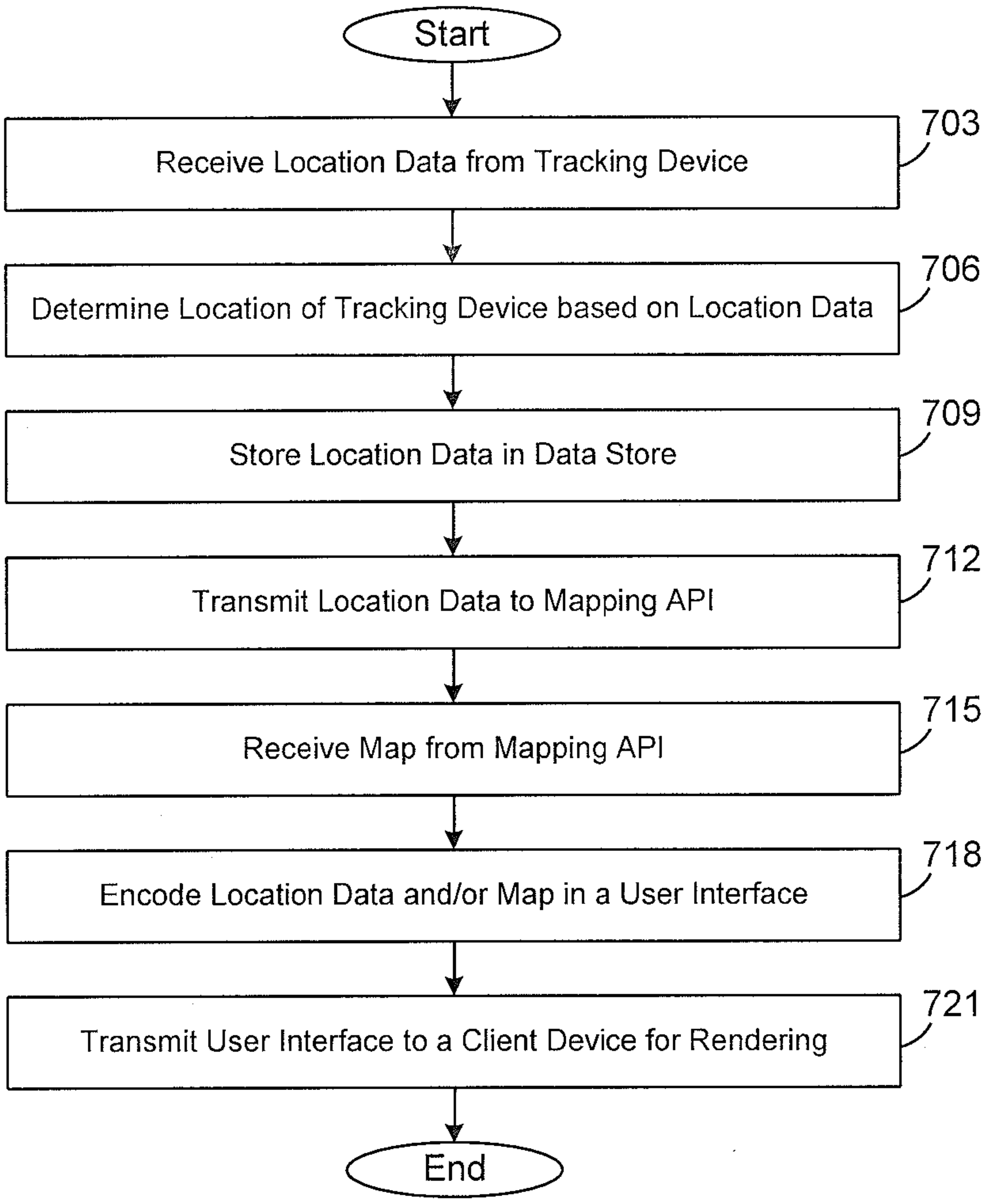
Start
Receive Location Data from Tracking Device
703
Determine Location of Tracking Device based on Location Data
706
Store Location Data in Data Store
709
Transmit Location Data to Mapping API
712
Receive Map from Mapping API
715
Encode Location Data and/or Map in a User Interface
718
Transmit User Interface to a Client Device for Rendering
721
End

FIG. 7

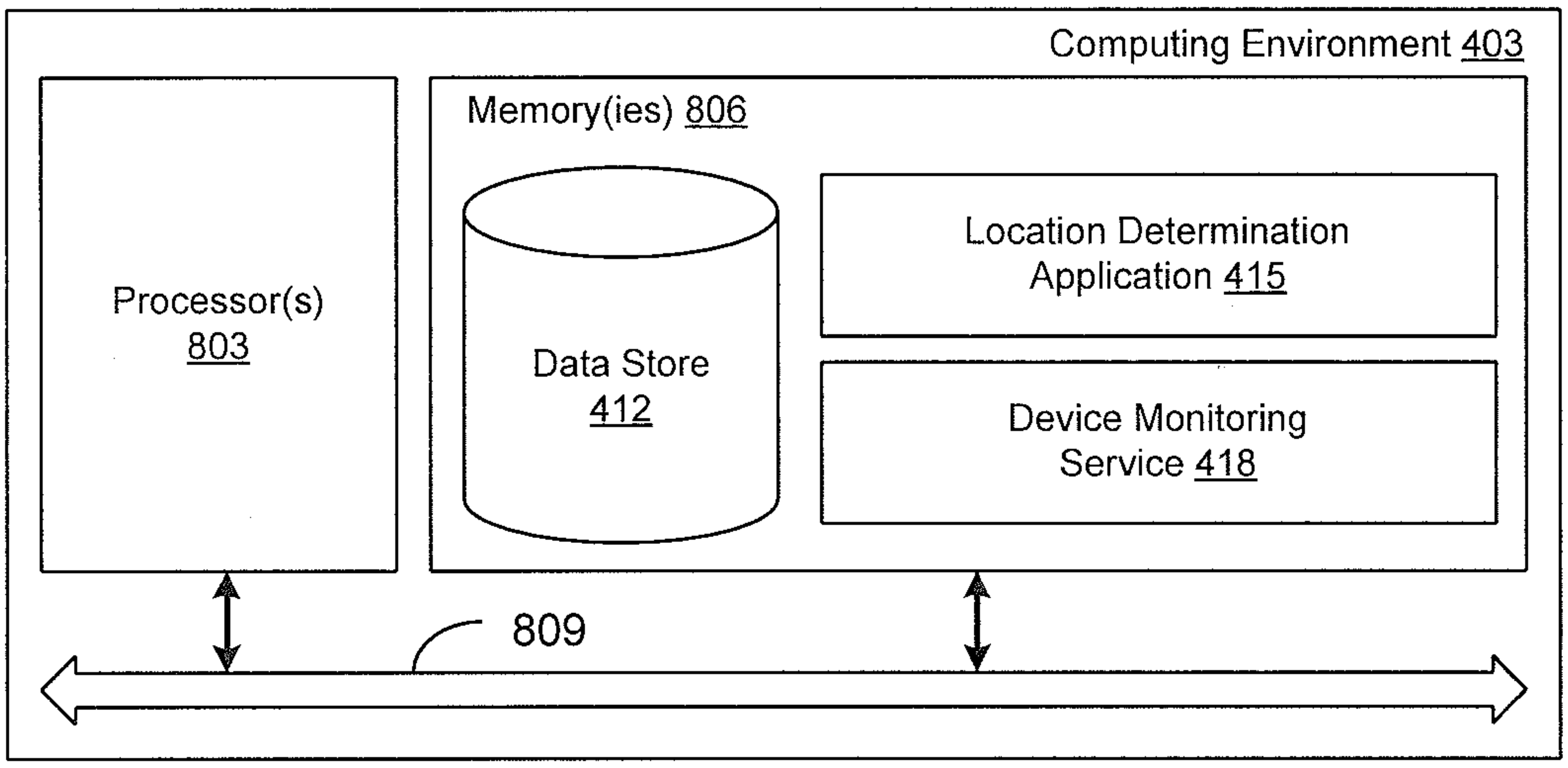
Computing Environment 403
Memory(ies) 806
Processor(s) 803
Data Store 412
Location Determination Application 415
Device Monitoring Service 418
809

FIG. 8

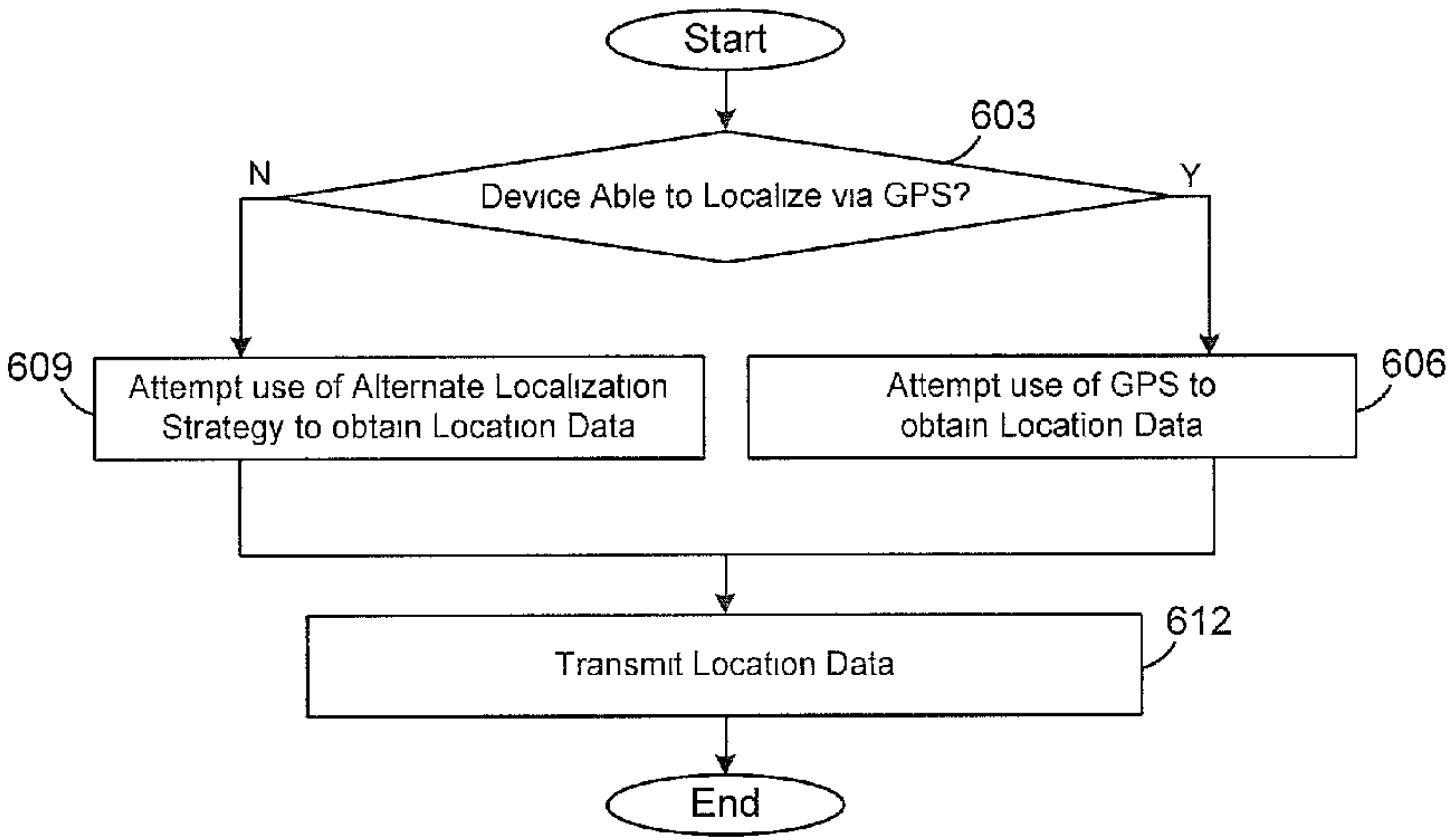
Start
603
N
Device Able to Localize via GPS?
Y
609
Attempt use of Alternate Localization Strategy to obtain Location Data
Attempt use of GPS to obtain Location Data
606
Transmit Location Data
612
End

FIG. 6