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McKeeman et al.

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(54) **METHOD FOR SWITCHING FROM A FIRST CELLULAR NETWORK TO A SECOND CELLULAR NETWORK**

USPC 455/436-439, 443, 456.1; 370/331, 332
See application file for complete search history.

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H04W 36/00 (2009.01)
H04W 4/00 (2009.01)
H04W 36/32 (2009.01)

(52) **U.S. Cl.**
CPC **H04W 36/32** (2013.01); **H04W 4/00** (2013.01)
USPC **455/437**; 455/436; 370/331

(58) **Field of Classification Search**
CPC . H04W 36/30; H04W 36/14; H04W 36/0083; H04W 24/08; H04W 4/021; H04W 16/18

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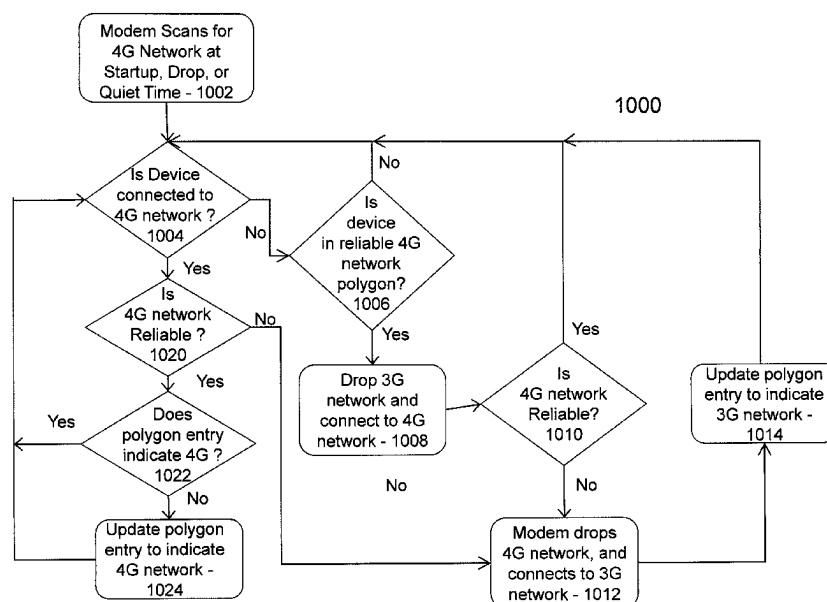
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(57) ABSTRACT

This invention provides a system and a method to automatically switch cellular data communications from 3G to 4G mode wherever reliable 4G cellular connectivity is available, and to collect and report reliable 4G cellular coverage geofence polygon information. The invention also provides a system and method to automatically switch cellular data communications between 4G cellular networks provided by different carriers, and 3G cellular networks provided by different carriers.

9 Claims, 10 Drawing Sheets



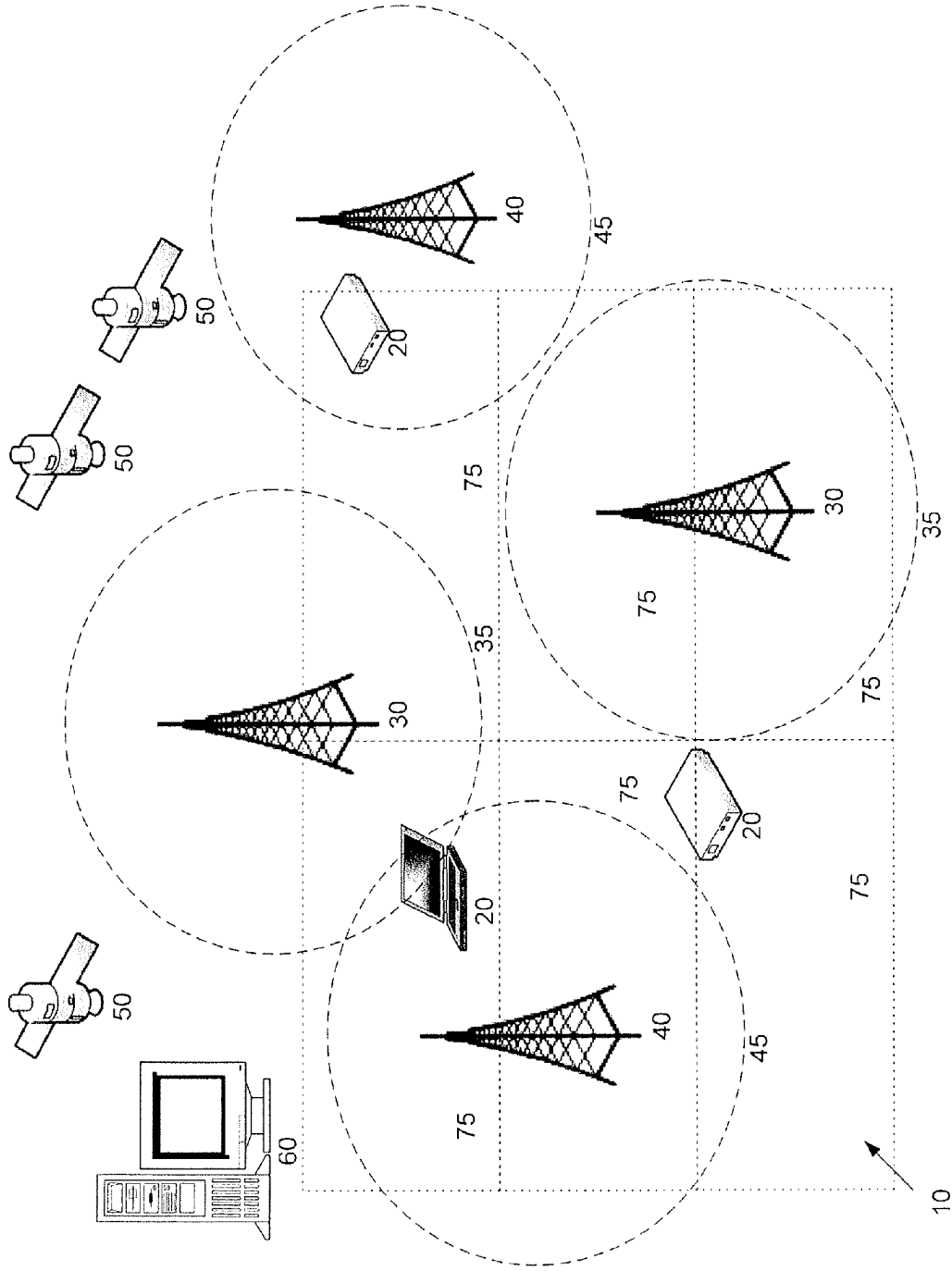


FIG. 1

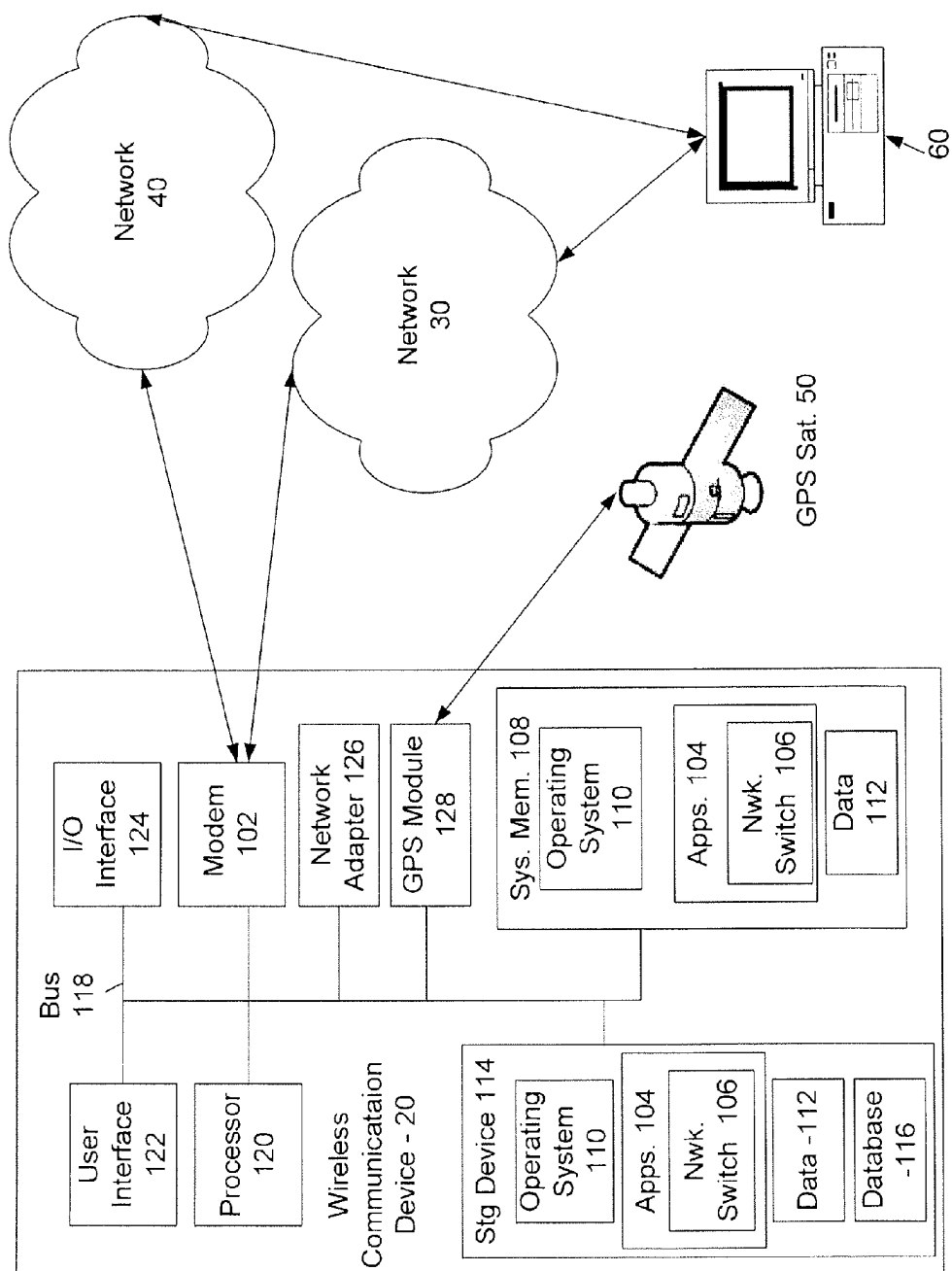


Fig. 2

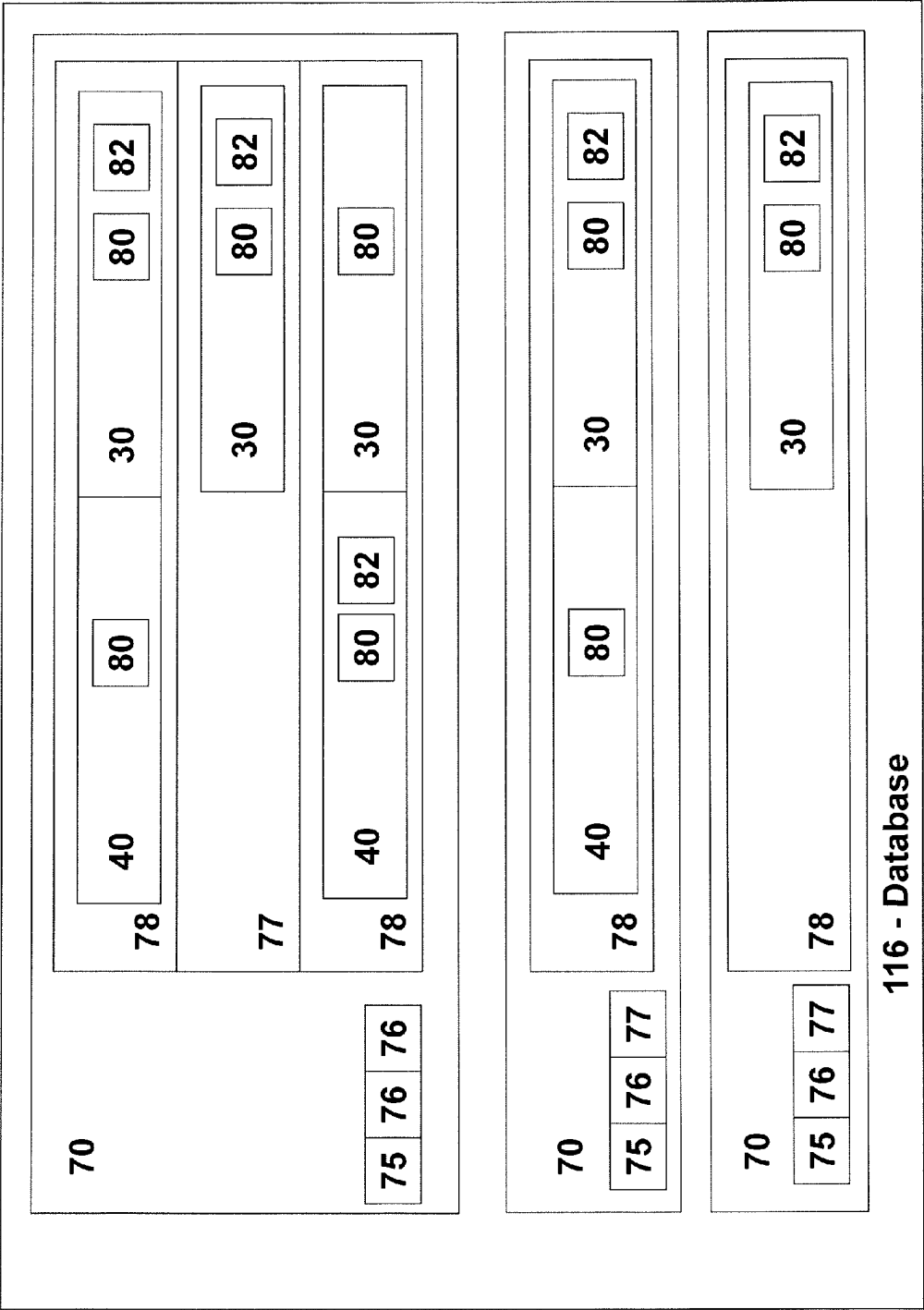


FIG. 3

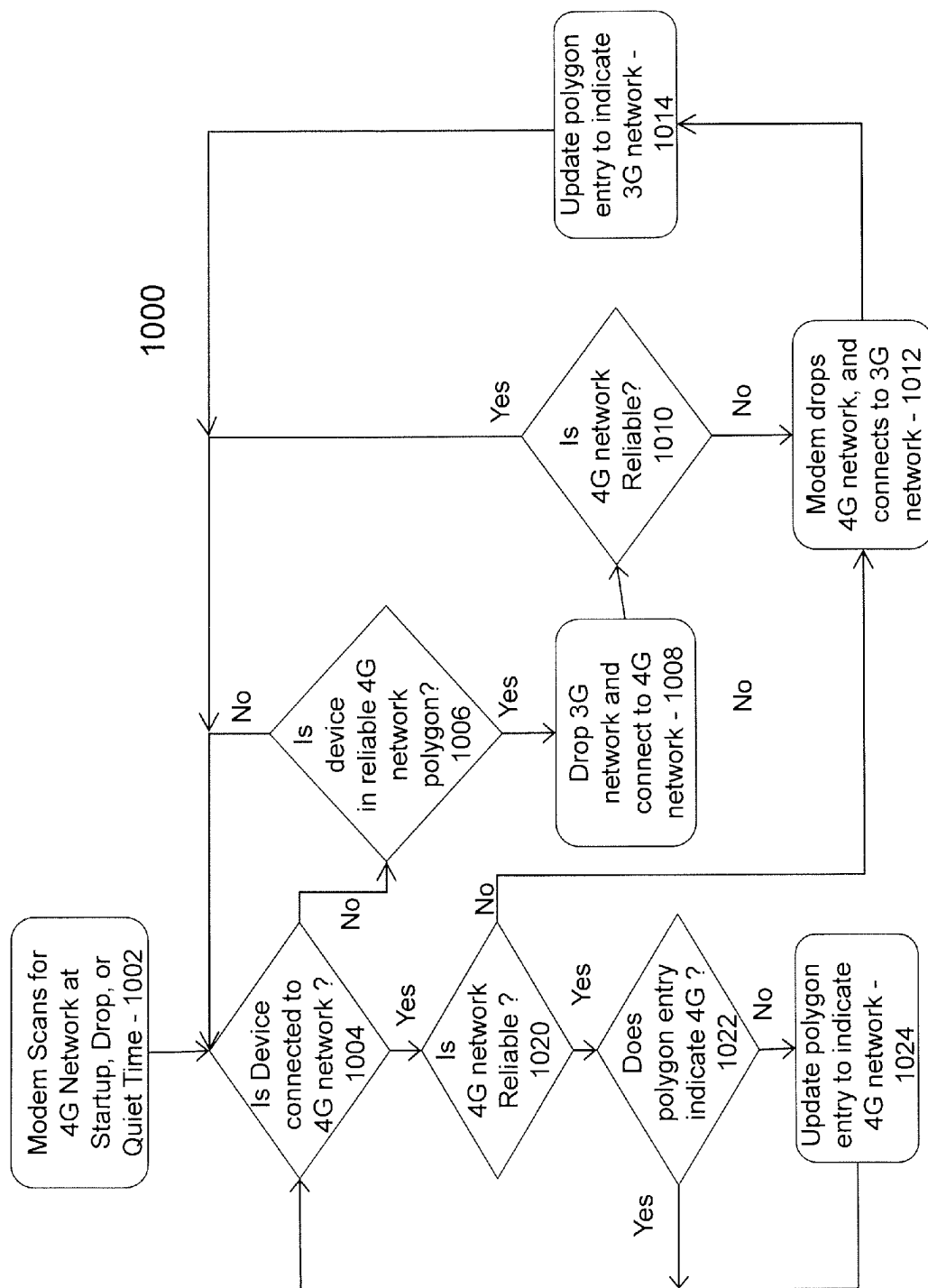


FIG. 4

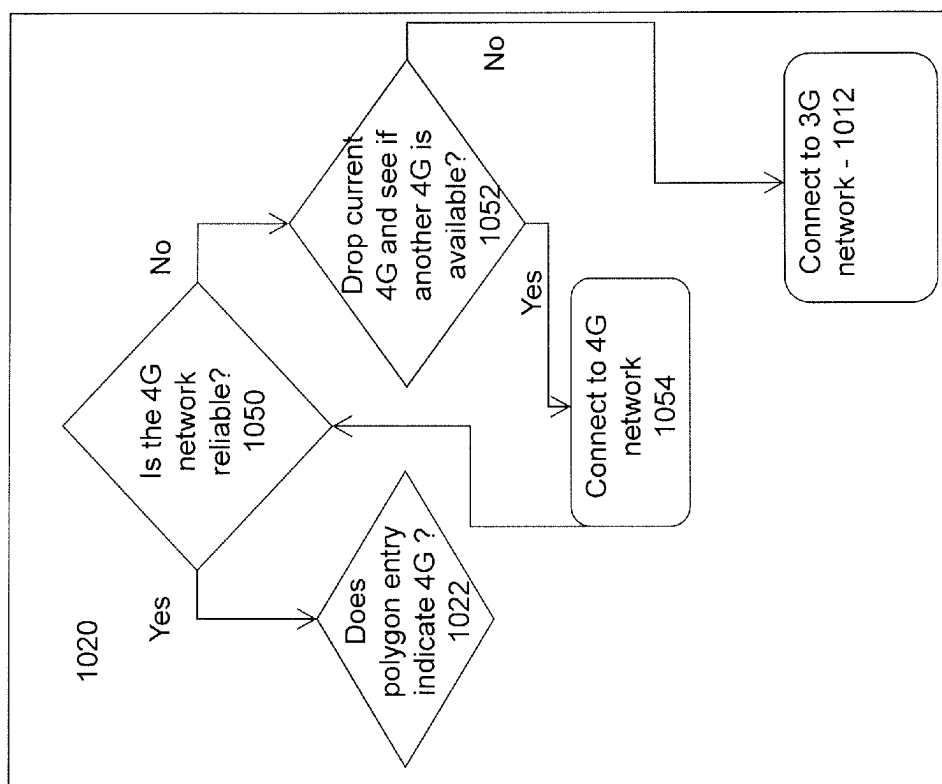


FIG. 4a

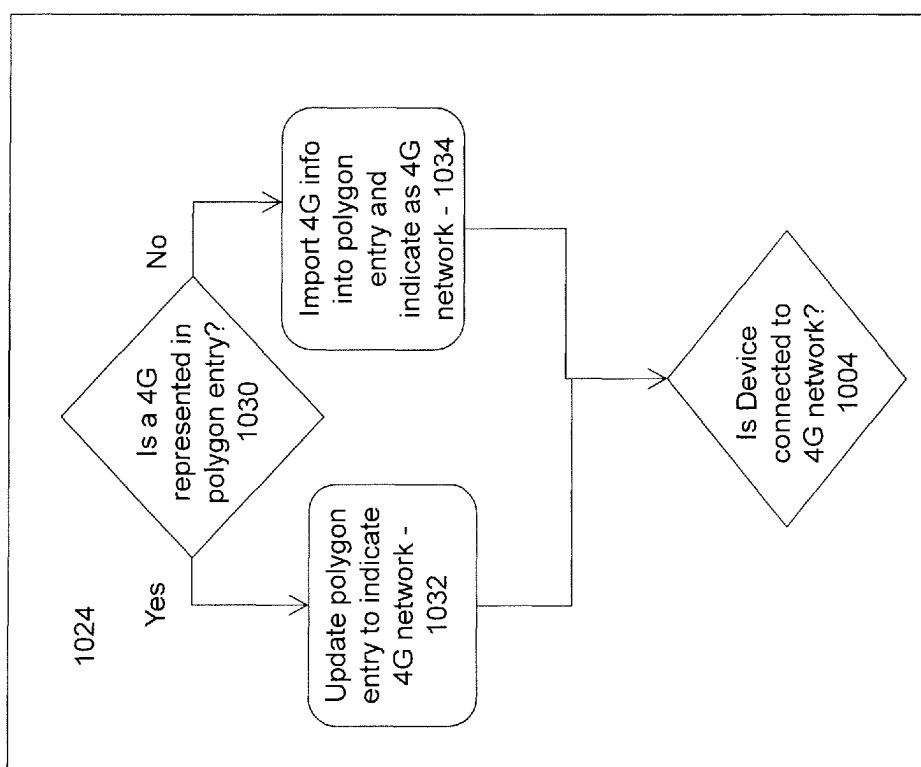


FIG. 5

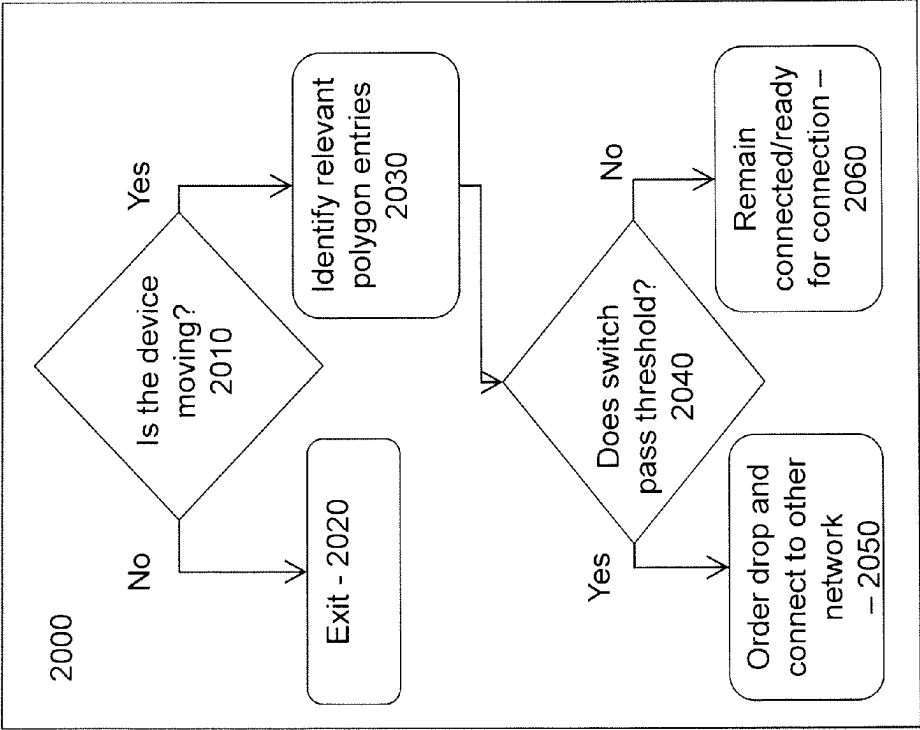


FIG. 6

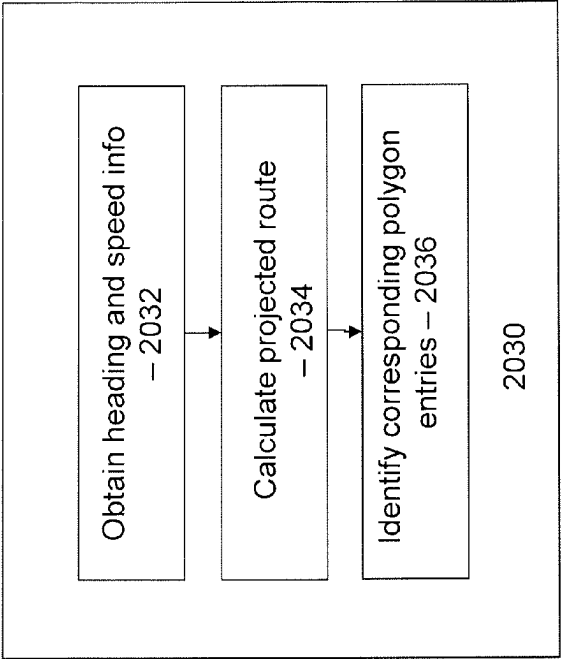


FIG. 7

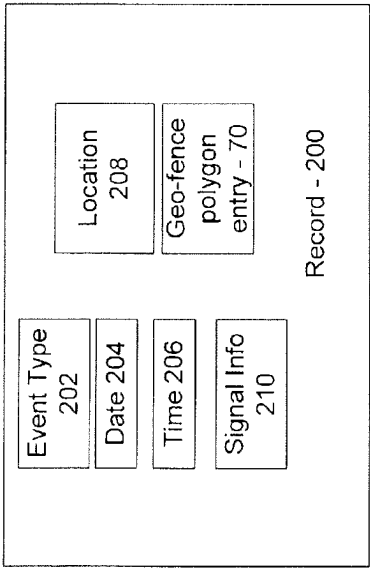


FIG. 8

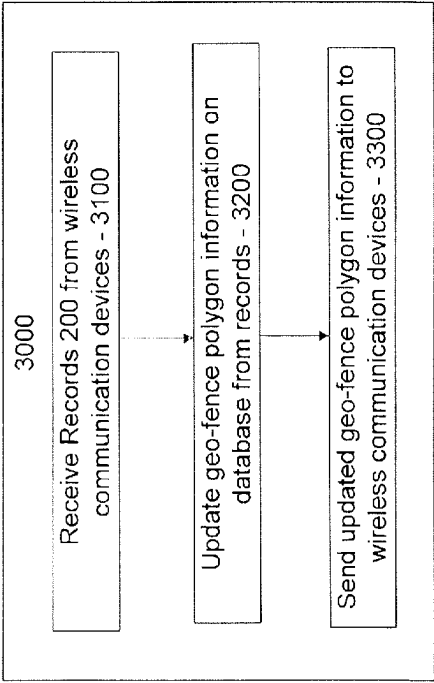


FIG. 10

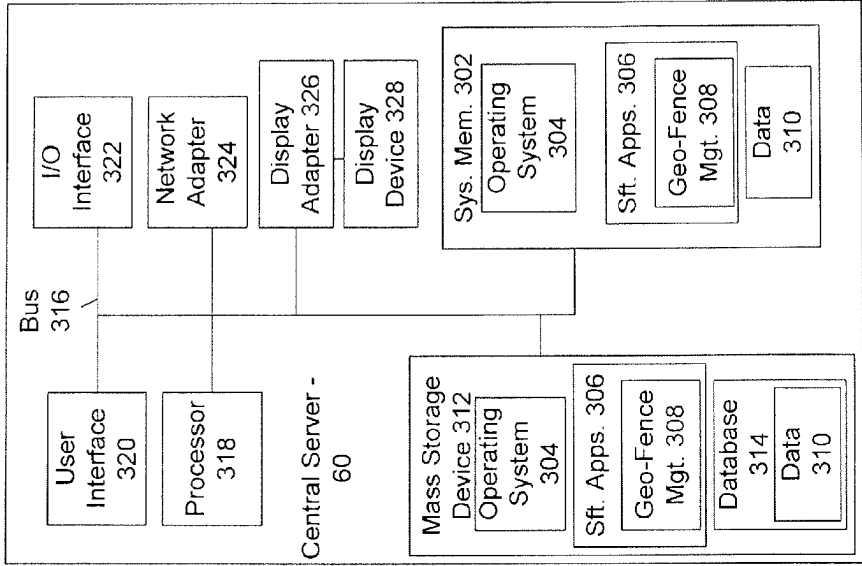


FIG. 9

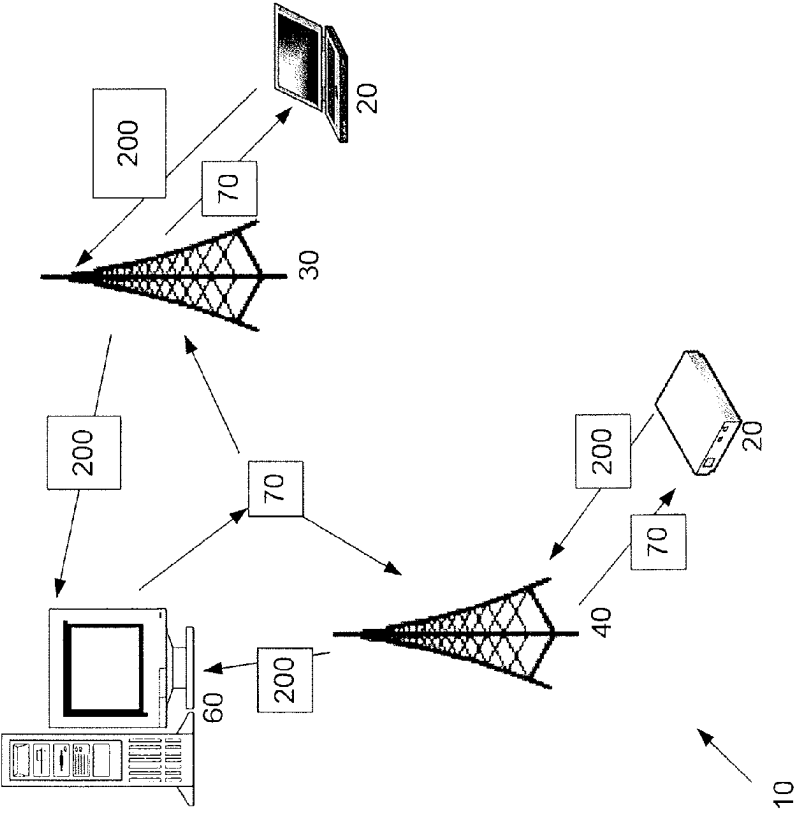


FIG. 11

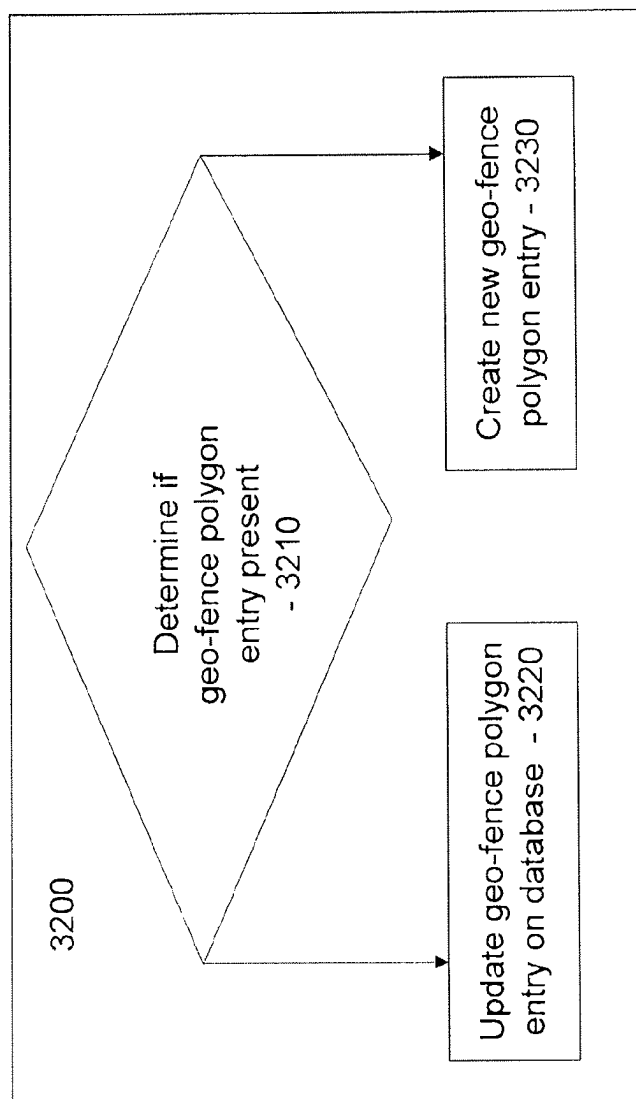


FIG. 12

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METHOD FOR SWITCHING FROM A FIRST CELLULAR NETWORK TO A SECOND CELLULAR NETWORK

CLAIM OF PRIORITY

This application is a continuation in part of U.S. patent application Ser. No. 13/594,047, filed on Aug. 24, 2012 and currently pending, which claims priority to U.S. Provisional Patent Application No. 61/526,998 filed on Aug. 24, 2011, each of which are relied upon and incorporated herein in its entirety by reference.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention is in the technical field of cellular data communications. More particularly, the present invention is in the technical field of managing the switching of wireless communication devices from a cellular data communications of a lower speed to a cellular data communications of a faster speed upon entering into the area of the faster speed cellular data communications.

2. Related Art

The wireless cellular industry is continuously upgrading their cellular data networks to improve their speed and increase the amount of data that is transmitted. Currently, wireless cellular providers are updating their networks from third generation (3G) cellular data communications to fourth generation (4G) cellular data communications. 4G cellular data communications provides upload and download bandwidth that is multiple times faster than 3G. Accordingly, cellular data users want to have their networking hardware operate in 4G mode if 4G mode is available at their current physical location.

Typically, the networking hardware of the cellular data user, such as, but not limited to, a 3G/4G capable modem found in a laptop, wireless router, or other wireless communication device, is used in a stationary manner, such as in an office, conference room, or the home of the user. If the networking hardware is within range of 4G cellular coverage upon activation, the networking hardware will utilize the 4G cellular communications. If there is no 4G cellular coverage at the location, and networking hardware is within the range of a 3G cellular network, the networking hardware will connect to the 3G cellular network. Such operation is fine when the networking hardware remains stationary or the user shuts down the networking hardware before moving from a 3G cellular network service area to a 4G cellular network service area and restarts a cellular data communication sessions as part of the move. Otherwise, the user will receive an error message via the networking hardware that the cellular data connection has been lost, and the user will manually restart the cellular communications connection using the vendor's cellular modem management software application associated with the networking hardware. The networking hardware cellular modem upon initial connection startup will connect to 4G service if it is available, then 3G service if 4G is not available, and then 2G service if 4G and 3G are not available.

However, there is a non-stationary use case of a 3G/4G cellular modem in a networking hardware—where the networking hardware is found within a vehicle in motion and therefore dynamically traveling in and out of 3G and 4G mode cellular coverage areas. For example, first responders (e.g., police, fire fighters, EMS, etc.), utility workers (e.g. gas, electrical, communications, water, etc.) and other industries that require workers or employees to work from a vehicle

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need to have a reliable and efficient communications connection back to their respective headquarters/dispatchers/information service providers. In such instances, the vehicle driver is not able to safely monitor and maintain the cellular data connection due to the vehicle driver having to drive the vehicle in addition to performing business-defined duties. Therefore, the networking hardware needs to autonomously manage the switching of cellular data communications between 3G and 4G mode as the vehicle travels about in and out of 3G and 4G cellular coverage areas in order to maintain the needed data connection.

Dual mode 3G/4G cellular modems partially address this problem. If a vehicle's networking hardware with a dual mode 3G/4G cellular modem is initially activated within a wireless access point offering 4G mode, the networking hardware will continue to operate in 4G mode until the vehicle travels outside of the 4G coverage area. Once out of the 4G coverage area, the networking hardware will lose or drop the 4G cellular data connection. If the networking hardware can no longer communicate with 4G cellular data towers, and the connection drops, the networking hardware will then automatically connect to 3G cellular coverage. This inherent assumption only is fulfilled if the 3G cellular coverage is available.

However, dual mode 3G/4G cellular modems cannot instantly detect when a vehicle has traveled from a 3G cellular coverage area back into a 4G cellular coverage area. 3G networks and 4G networks operate at different frequencies (i.e., 840/1900 MHz for 3G and 700 MHz for 4G). Since dual mode 3G/4G cellular modems can only operate at one frequency at a time, thereby only being connected to one cellular network at a time, the dual mode 3G/4G cellular modem is unable to monitor and connect to both the 3G and 4G networks simultaneously. Once networking hardware is actively communicating on a 3G cellular network, it is actively transmitting data and therefore cannot scan for other frequencies such as 4G networks. When the networking hardware enters into a "quiet time", a period of not transmitting data, the networking hardware can scan for other networks. However, if actively communicating in a 3G network, the networking hardware will continue to operate in 3G mode regardless of whether a vehicle drives back into a 4G cellular coverage area. Quiet periods are few and far between for networking hardware that is employed for public safety purposes, wherein the wireless device is constantly sending and receiving critical information, such as GPS position and computer aided dispatch data, as well as other data types. In addition, these wireless devices communicate "heartbeat" and socket "keep alive" messages. So a 3G/4G networking hardware operating in 3G mode has limited ability to determine that 4G cellular coverage might be available where the vehicle is now located—either stopped or in motion as the vehicle continues to travel. As such, the networking hardware often remains connected to the cellular data communications in slower 3G mode even if the vehicle and the networking hardware have traveled into a reliable 4G cellular coverage area.

As a result, a system and method is needed to determine when a vehicle—and therefore the vehicle networking hardware installed or contained in the vehicle—has traveled into a reliable 4G cellular coverage area while still connected to a 3G cellular network. If the networking hardware has traveled into a 4G coverage area, the networking hardware must somehow determine it is now located in a reliable 4G cellular data coverage area. Once the networking hardware determines that it is in a known reliable 4G cellular coverage area, the networking hardware can then disconnect from the 3G cellular coverage and connect to the 4G cellular coverage, regard-

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less of whether the modem itself knows the vehicle has traveled into a reliable 4G service area. Further, the networking hardware needs to manage this 3G to 4G switching process automatically as a vehicle drives in and out of 3G and 4G cellular coverage areas.

In addition, there is a need for a system and method to determine the availability and reliability of 4G cellular coverage at any given location. A system and method is needed to continuously collect information about the actual current reliable 3G and 4G cellular coverage areas, and make that information available on a shared basis to other networking hardware in other vehicles so that any related networking hardware has the maximum ability to operate in the much higher bandwidth that 4G cellular data communications provides.

SUMMARY OF INVENTION

The present invention is a system and method for switching a wireless communication device in a vehicle to the most reliable cellular communications within a cellular network coverage area.

One embodiment of the present invention manages the switching of the wireless communication device from a 3G cellular communications to a 4G cellular communications by monitoring active connections of the wireless communication device, reviewing the reliability information of the networks associated with the geo-fence polygon that corresponds to the location of the wireless communication device, and directing the wireless communication device to connect to the proper network.

One embodiment of the present invention can optionally capture and report drops and discoveries of reliable 3G and 4G coverage records with date, time, GPS location coordinates, signal quality, service area polygon/grid cell ID, and other data elements when coverage is determined to be available in a geo-fence polygon. Additional embodiments may update and/or create geo-fence polygon entries based upon the information obtained.

Another embodiment of the present invention includes using the collective 4G coverage discovery and/or drop records collected from wireless communication devices of the enterprise vehicle fleet to a central database of geo-fence polygon entries. The system and method may also aggregate discovery and/or drop records from the wireless communication devices of multiple enterprise vehicle fleets into a central database of discovery and/or drop records, where multiple enterprises can leverage and benefit from discovery and/or drop records captured and reported by wireless communication devices from other enterprise fleets.

Another embodiment of the present invention includes distributing updated 4G discovery and drop geo-fence polygon information from a central database to all the wireless communication devices of the enterprise fleet and/or across multiple enterprise fleets so that all the wireless communication devices for multiple enterprise fleets all have access to the most recent set of reliable 4G geo-fence coverage polygon information as reported by any system wireless communication devices. Another embodiment of the present invention periodically includes distributing reliable 4G geo-fence coverage polygon information from the central database to a local database located on the wireless communication devices. The updated information documenting discoveries, drops, and the reliability of networks may be in the form of updated geo-fence polygon database entries.

Another embodiment of the present invention may include modules operating on the wireless communication devices

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that interrogate and obtain current GPS location from a GPS module associated with the wireless communication device, and compares the current GPS location of the wireless communication device of the vehicle to a local database of reliable 4G geo-fence coverage polygon information to determine if the vehicle and the wireless communication device are currently located in a reliable 4G coverage polygon.

Another embodiment of the present invention may include a system and method for switching a wireless communication device in a vehicle from 3G or 4G cellular communications provided by a first cellular carrier to another 3G or 4G cellular communications provided by a second cellular carrier when the vehicle enters into a 3G or 4G cellular communications coverage area that is more reliable than the first cellular carriers 3G or 4G cellular communications coverage area that shares the same location.

These and other objects and advantages of the invention will become apparent from the following detailed description of the preferred embodiment of the invention.

Both the foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the invention as claimed. The accompanying drawings are included to provide a further understanding of the invention and are incorporated in and constitute part of this specification, illustrate several embodiments of the invention, and together with the description serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an automated cellular network switching system according to an embodiment of the present invention.

FIG. 2 is a block diagram of a wireless communication device of the automated cellular network switching system of FIG. 1 according to an embodiment of the present invention.

FIG. 3 is a more detailed view of a component of the block diagram of FIG. 2.

FIG. 4 is a flow diagram of a method performed by a wireless communication device according to an embodiment of the present invention.

FIG. 4a is a flow diagram of part of the method of FIG. 4 according to an embodiment of the present invention.

FIG. 5 is a flow diagram of part of the method of FIG. 4 according to an embodiment of the present invention.

FIG. 6 is a flow diagram of a method performed by a wireless communication device according to an embodiment of the present invention.

FIG. 7 is a flow diagram of part of the method of FIG. 4 according to an embodiment of the present invention.

FIG. 8 is a block diagram of the central server of the system of FIG. 1 according to an embodiment of the present invention.

FIG. 9 is a block diagram of a record according to an embodiment of the present invention.

FIG. 10 is a flow diagram of a method of updating a central database performed by the system of FIG. 1 according to an embodiment of the present invention.

FIG. 11 is a block diagram of a system illustrating the performance of selected portions of the updating of the central database.

FIG. 12 is a flow diagram illustrating portions of the updating method of FIG. 10.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In the following detailed description of the preferred embodiments, reference is made to the accompanying draw-

ings, which form a part hereof, and within which are shown by way of illustration specific embodiments by which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the invention.

Referring to FIG. 1, the present invention is directed to an automated wireless network switching system **10** that automatically identifies and establishes connections for wireless communication devices **20** to a first wireless network **30** and a second wireless network **40** of differing mobile communication standards depending on the current and future locations of wireless communication devices **20** in the coverage areas **35**, **45** of such networks **30**, **40**. In some embodiments of the present invention, the automated cellular network switching system **10** may utilize Global Positioning System (GPS) satellites **50** and a central server **60**, which may be able to communicate over and/or through the wireless cellular networks **30**, **40** with the wireless communication devices **20**, to further enhance the automatic switching of the networks **30**, **40** for the wireless communication devices **20** as they move among different coverage areas **35**, **45**. According to one embodiment, the automated wireless networking system **10** is directed at controlling the switching of wireless communication devices **20** between a first cellular network **30** and second cellular network **40** of differing mobile communication standards (e.g., 3G and 4G). However, in other embodiments, the automated wireless networking system **10** may control the switching between varieties of wireless networks, as discussed below.

As shown in FIGS. 1-2, the automated wireless network switching system **10** is an automated cellular network switching system **10** that includes at least one wireless communication device **20**. Examples of the wireless communication devices **20** utilized by the automated wireless network switching system **10** include, but are not limited to, laptops, wireless routers, wireless vehicle routers (e.g., Utility Associates Rocket, Sierra Wireless GX440, and wireless vehicle routers by InMotion and BlueTree), tablets, smart phones, PDA's, hand held computers, and the like. The only limitation is that the wireless communication device **20** has some means of communicating on multiple generations of cellular networks, including, but not limited to current generations like 3G, 4G networks, and future generations, including the proposed 5G network.

The wireless communication devices **20** include a modem **102**. In the preferred embodiment of the present invention, the modem **102** is a cellular modem capable of communicating on 3G and 4G networks. Embodiments of the present invention are not limited to cellular modems **102** only capable of communicating on 3G and 4G networks. The invention encompasses modems **102** capable of communicating on 2G, 3G, 4G, and 5G networks, other communication networks, including satellite networks, as well.

In some embodiments, the invention encompasses modems **102** that are capable of communicating on cellular networks of multiple cellular network carriers. In one example of such an embodiment, the modem **102** can communicate on multiple 4G LTE cellular networks provided by different carriers that operate on different 700 MHz bands (e.g., AT&T and Verizon). In another example of the present embodiment, the modem **102** can operate on multiple 4G cellular networks operating on different frequency bands (e.g., Sprint on 1900 MHz, T-Mobile on 1700 MHz, and AT&T and Verizon on 700 MHz). In another example of the present embodiment, the modem **102** can operate on multiple different 3G and 4G cellular networks of different carriers, as

well as on different types of networks (e.g., the FirstNet private Public Safety Broadband Network on a 700 MHz band).

In addition, some modems according to other embodiments of the present invention are directed to communicate on public and private networks. For example, embodiments of the present invention encompass modems capable of communicating on the New York City government private NYCWIN 2.5 Ghz 4G LTE network voice and data network built after 9/11, and the private Public Safety Broadband Network (PSBN) included in the federal law 2012 HR 3630. Switching between public carrier networks and private networks (e.g. PSBN) present similar issues when the private network is unavailable.

The cellular modem **102** may be embedded within the wireless communication device **20** or be self-standing and connected to the wireless communication device **20** through various means, including, but not limited to, a USB connection. Examples of cellular modems include, but are not limited to, AT&T Momentum, Verizon 551L, USB cellular modems and motherboard mounted cellular chipsets manufactured by Novatel Wireless, Sierra Wireless, Huawei, and the like. In addition, the modem **102** may operate switching between cellular and satellite communications. Such a modem may include, but is not limited to, a Galaxy 1 BGAN terminal.

The modem **102** is configured to automatically connect to a slower network when the faster network is not available. For example, in one embodiment, the cellular modem **102** automatically connects to a 3G cellular network **30** if not within the coverage area **45** of a 4G cellular network **40** upon start up or in the case that a connection to a 4G cellular network **40** is dropped. This occurs as long as the wireless communication device **20** is within a coverage area **35** of a 3G network **30**. The modem will attempt **102** to connect to a slower 2G service, such as EDGE/1xRTT, if 3G CDMA/GSM/HSPA and equivalents are not available. In another embodiment, the modem **102** can automatically connect to a 3G cellular network **30** or 4G cellular network **40** of another provider if the modem **102** enters into another coverage area **35/45** where the current 3G cellular network **30** or 4G cellular network **40** is not available.

The cellular modem **102** is configured to also monitor the reliability of all connections. The reliability of a network can be determined from information collected by the cellular modem **102**, which includes, but is not limited to, signal strength, quality, availability, packet loss, retransmits, packet latency, throughput speed, and other cell tower signaling quality factors. The cellular modem **102** will compare this information in various forms to a reliability threshold in order to determine whether or not to maintain or terminate a connection to a cellular network. The reliability threshold is often automatically set by the cellular carrier, or manually set by the user of the wireless communication device **20**, and can vary by the numerous factors discussed above.

The cellular modem **102** is configured to establish a connection with cellular networks in which the cellular modem **102** is located. The cellular modem **102** is configured to monitor and detect 3G and 4G cellular networks **30**, **40** as the cellular modem **102** moves from one network coverage area **35** to another network coverage area **45** via the vehicle in which it is contained. The cellular modem **102** can detect when a connection to a particular network is made, whether it is a 3G or 4G network **30**, **40**, as well as which cellular network provider (e.g., Verizon, T-Mobile, etc.) it has connected to. When in a "quiet" period, such as when it is not actively transmitting data or establishing a connection, the

cellular modem 102 can scan frequencies to see if a cellular network 30, 40, new or established, is available. The “quiet” periods can occur when the wireless communication device 20 starts up in a grid cell, when a connection drops and the modem 102 does a reconnect, or in instances when it is not actively transmitting data. The cellular modem 102 can determine the signal strength, quality, availability, carrier provider and throughput of the cellular network 30, 40 in which it is located, and report such information to a network switching application 106, discussed below.

In addition to the cellular modem 102, the wireless communication device 20 can have several applications 104, including the network switching application 106. The wireless communication devices 100 include system memory 108, which can store the various applications 104, including, but not limited to, the operating system 110 of the wireless communication device 20 and the network switching application 106. The system memory 108 may also include data 112 accessible by the various software applications. The system memory 108 can include random access memory (RAM) or read only memory (ROM). Data 112 stored on the wireless communication device 20 may be any type of retrievable data. The data may be stored in a wide variety of databases, including relational databases, including, but not limited to, Microsoft Access and SQL Server, MySQL, INGRES, DB2, INFORMIX, Oracle, PostgreSQL, Sybase 11, Linux data storage means, and the like.

The wireless communication device 20 can include a variety of other computer readable media, including a storage device 114. The storage device 114 can be used for storing computer code, computer readable instructions, program modules, various databases and other data for the communication device 20, and the storage device 114 can be used to back up or alternatively to run the operating system 110 and/or other applications 104, including the network switching application 106. The storage device 114 may include a hard disk, various magnetic storage devices such as magnetic cassettes or disks, solid-state flash drives, CD-ROM, DVDs or other optical storage, random access memories, and the like.

Referring to FIG. 3, in some embodiments of the present invention, the storage device 114 includes a database 116 for geo-fence polygon entries 70 that include geo-fence polygons 75 for the respective coverage area 35, 45 of the 3G and 4G cellular networks 30, 40. The database 116 may be relational databases or other known forms of databases. The geo-fence polygons 75 are virtual perimeters to represent the real-world geographic area or boundaries of areas within the coverage areas 35, 45 of the 3G and 4G cellular networks 30, 40 respectively. The geo-fence polygon 75 includes the known coordinates (e.g., longitude and latitude of area) of a particular boundary.

The geo-fence polygons 75 may be defined along a range of spatial levels, from higher levels to very granular levels. The geo-fence polygons 75 may be defined by different shapes, such as squares, rectangles (as shown in FIG. 1), or irregular shaped polygons. In one embodiment of the present invention, the geo-fence polygons 75 may be defined by Google Map Layers, ranging from Google map level 24 (measured in tiles that are approximately 2.4 meters square) to Google map level 16 (640 meters squared) to higher levels. In other embodiments, the polygons may directly follow riverbeds or national boundaries on a side. The more accurately the geo-fence polygons 75 are defined, the greater the accuracy of finding reliable network coverage.

Geo-fence polygon entries 70 are made for each specific geo-fence polygon 75. Each geo-fence polygon entry 70

includes an identifier 76 and the coordinates 77 of the geo-fence polygon 75 and the cellular network type 30, 40 whose coverage areas 35, 45 extend within the area defined by the geo-fence polygon 75. In some embodiments, the entry 70 may include the carrier identity 78 (i.e., Verizon, AT&T, Sprint, etc.) of the networks 30, 40 that reside within the area defined by the geo-fence polygon 75, as shown in FIG. 3.

The geo-fence polygon entries 70 of the database 116 may also include reliability data 80 of the cellular network 30, 40 coverage area 35, 45 retained within the geo-fence polygon 75. The reliability data 80 includes, but is not limited to, the signal strength, quality, availability, packet loss, retransmits, packet latency, throughput speed, and other cell tower signaling quality factors of the 3G/4G cellular network 30/40 defined by the geo-fence polygon 75. Such information is important because reliability data cannot be generalized due to the unpredictable effects that the topography of such coverage areas, such as valleys and mountain ranges, top of hills, bottom of hills, and various manmade structures, including buildings, bridges of iron and concrete etc., have on radio wave propagation. The geo-fence polygon entry 70 may also include a reliability indicator 82, which indicates whether or not the available 3G or 4G network 30, 40 is the reliable network within the geo-fence polygon 75 the wireless communication device 20 should utilize.

Since the coverage area 35, 45 of 3G and 4G cellular networks 30, 40 often overlap, a geo-fence polygon entry 70 may include information for all the 3G, 4G cellular networks 30, 40 operating within the geo-fence polygon 75, including the carrier identifiers 78 and associated reliability data 80 for each. Since some modems 102 communicate only with one carrier, it is possible to limit the information of the geo-fence polygon entry 70 to a single carrier. However, some modems 102 can communicate with multiple carriers. In either case, a geo-fence polygon entry 70 is not limited to information related to only one carrier. For example, the geo-fence polygon entries 70 maintained by the central server 60 can include information for multiple cellular networks of multiple carriers that are found within a given geo-fence polygon 75. The geo-fence polygon entries 70 may be supplied from information obtained directly from the network carriers, or may be assembled from information collected by the wireless communication devices 20, as explained in more detail below.

The network switching application 106 utilizes the information within each geo-fence polygon entry 70, including the geo-fence polygon 75 and its coordinates 77 and reliability data 80, to maintain the optimum cellular network connection. While the geo-fence polygon entries 70 may be found within a database 116 maintained on the storage device 114, the geo-fence polygon entries 70 may be stored on the RAM of the storage memory 108 in a limited fashion in other embodiments of the present invention.

The geo-fence polygon database 116 may be updated by the network switching application 106 when the cellular modem 102 discovers additional information about the cellular networks 30, 40. In additional embodiments, the geo-fence polygon database 116 maintained within the storage device 114 may be updated by the central server 60, or the central server 60 may provide limited geo-fence polygon data to the wireless communication device 20 for utilization by the system memory 108 based upon the location of the wireless communication device 20. In such situations, the network switching application 106 may call upon a central server 60 to provide geo-fence polygon data of other areas in which the wireless communication device 20 may enter based upon the direction its travel and speed, which may be determined by various means discussed below.

The wireless communication device **20** may include a system bus **118** that connects various components to the system memory **108** and to the storage device **114**, as well as to each other. Other components of the wireless communication device **20** may include one or more processors or processing units **120**, a user interface **122**, an input/output interface **124**, and a network adapter **126** that is configured to communicate with other devices over various networks.

In addition, some embodiments of the wireless communication device **20** may include a GPS module **128** that is configured to continuously communicate with GPS satellites **50** discussed above in order to obtain the location (for example, the latitude and longitude) of the wireless communication device **20**. In some embodiments of the present invention, such information may be collected once per second. However, the rate of obtaining such information varies depending on the needs of the wireless communication device **20**. When the wireless communication device **20** is in motion (i.e., when a moving vehicle), the GPS module **128** is configured to obtain the heading and the speed of the wireless communication device **20** through repeated data transmissions from the GPS satellites **50**. For example, the GPS module **128** may be configured to determine the direction of travel in compass degrees from 0 to 360. The GPS module **128** may also calculate and report the travel speed of the wireless communication device **20** based upon the location information obtained, including the distance between two position location reports and the time it took to travel that distance. In some embodiments of the present invention, the GPS module **128** may reside on a chip set embedded within the wireless communication device **20** with an external antenna or an external GPS receiver. Examples of such chip sets include, but are not limited to, the SiRFSTAR III and SiRFSTAR IV GPS chip sets. As such, the GPS related information (latitude, longitude, speed, heading, and potentially altitude) may be calculated by the wireless communication device through the GPS module **128**. While some embodiments of the present invention utilize a GPS module **128** in order to obtain the location, speed, and heading of the wireless communication device **20**, other embodiments may be able to obtain such information through other sources and devices, such as, but not limited to, vehicle's speedometer and other navigational systems or wherever reliable real-time GPS data means. Such means may include triangulating cellular devices between multiple cell towers or other known location methods.

The network switching application **106** is configured to control the operation of the cellular modem **102** to ensure that the wireless communication device **20** is connected to the most reliable and efficient 3G or 4G cellular network **30**, **40** available. In some embodiments, the network switching application **106** can connect the cellular modem to the most reliable and efficient cellular network **30**, **40** available, regardless of network carrier. The network switching application **106** may utilize data from the cellular modem **102**, the geo-fence polygon entries **70** stored in the database **116** of the storage device **114** or the system memory **108**, and the GPS module **128** or other location and direction providing means to switch connections of the cellular modem **102** from a 3G cellular network **30** to a 4G cellular network **40** and vice versa.

FIG. **4** depicts a flow diagram **1000** that illustrates the operation of the network switching application **106** according to one embodiment of the present invention. Whenever the cellular modem **102** starts operating, has dropped and is restarting a connection, or has a "quiet" time of no data transmission, the cellular modem **102** will scan for the availability of a 4G cellular network **40** (step **1002**). If the cellular

modem **102** is able to connect to a 4G cellular network **40**, it does so. If not, the cellular modem **102** will connect to a 3G cellular network **30**. The switching application **106** will then determine whether or not the cellular modem **102** is connected to a 4G cellular network **40**, or if a 4G cellular network **40** is available (step **1004**).

If the cellular modem **102** is not connected to a 4G cellular network **40**, the network switching application **106** can use current location information, obtained by the GPS module **128** or other known means, to calculate the present location of the wireless communication device **20** and find the corresponding geo-fence polygon entry **70** to determine if the wireless communication device **20** is currently located in a reliable 4G network **45** service area polygon **75** (step **1006**).

If the wireless communication device **20** is in a geo-fence polygon **75** that includes a reported reliable 4G cellular service area **45** provided by a carrier **78** that the modem **102** utilizes, the network switching application **106** will force the cellular modem **102** to drop an active 3G connection, and initiate a connection to the 4G cellular network **40** within the service area **45** (step **1008**). The reliability of the coverage area **45** of the cellular network **40** within the given geo-fence polygon **75** may be indicated with the reliability indicator **82**. In such cases in which the modem **102** is capable of operating on multiple 3G and/or 4G cellular networks **30/40** (i.e., the modem can operate on cellular networks provided by different carriers), the network switching application **106** can direct the modem **102** to connect to the 3G network **30** or 4G cellular network **40** of the carrier that has the higher(est) reliability within the polygon **75**.

Once the cellular modem **102** has switched to the 4G cellular network **40**, the cellular modem **102** will determine whether or not the connection within the network coverage area **45** is actively reliable (step **1010**). The cellular modem **102** may look to the signal strength, quality, availability, packet loss, retransmits, packet latency, throughput speed, and other signaling quality factors for such a determination, comparing such information to one or more reliability thresholds that must be met in order for the 4G cellular network **40** to be considered reliable. At this point, it is possible for the network switching application **106** to update the reliability data **80** of the corresponding geo-fence data entry **70** with the information obtained by the cellular modem **102**. If the cellular modem **102** determines the 4G cellular network **40** is reliable, the cellular modem **102** maintains the 4G connection and the network switching application **106** returns to step **1004**. The reliability thresholds may simply be a value that the signal strength, quality, availability, packet loss, retransmits, packet latency, or throughput speed are compared to, or a value after the aforementioned inputs are combined.

If the cellular modem **102** determines the 4G connection of the 4G cellular network **40** provided by the carrier **78** of the cellular modem **102** is not reliable or inadequate, the cellular modem **102** can drop the 4G connection, and re-establish the 3G connection with the 3G cellular network **30** (step **1012**). The network switching application **106** will determine that the 4G connection was dropped, even though the geo-fence polygon entry **70** reports the 4G network **40** within the geo-fence polygon **75** as reliable through the reliability indicator **82**. The network switching application **106** will obtain the current location of the wireless cellular device **20** and use that to determine the corresponding geo-fence polygon entry **70** and geo-fence polygon **75** for the 4G service area **45** in which the wireless cellular device **20** is located. The network switching application **106** will update the corresponding geo-fence polygon entry **70** (step **1014**), including marking the 4G network **40** of the carrier **78** of the cellular modem **102** as

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unreliable for 4G connectivity or removing the reliability indicator **82**, and designating the corresponding 3G cellular network **30** as the reliable network with the reliability indicator **82**. The network switching application **106** may report the updated reliability data **80** of the 4G connection quality and GPS position data to database **116** of the central server **60**.

Returning to step **1004**, if the network switching application **106** determines the cellular modem **102** is connected to a 4G cellular network **40**, the cellular modem **102** will determine whether or not the 4G cellular network **40** is reliable (step **1020**). If the cellular modem **102** finds the 4G cellular network **40** unreliable, as described in step **1010**, the cellular modem **102** will disconnect from the 4G cellular network **40** and connect to the available 3G cellular network **30** (step **1012**).

If the cellular modem **102** determines that the 4G cellular network **40** is reliable, the network switching application **106** will determine if the corresponding geo-fence polygon entry **70** indicates the 4G cellular network **40** as the reliable network within the geo-fence polygon **75**, as indicated by the reliability indicator **82** (step **1022**). If the 4G cellular network **40** of the corresponding geo-fence polygon entry **70** is reported as reliable (having the reliability indicator **82**), the network switching application returns to step **1004**. If the network switching application **106** finds that the reliability indicator **82** is associated with the 3G cellular network **30** of the corresponding geo-fence polygon entry **70**, the geo-fence polygon entry **70** is updated to show the 4G cellular network **40** is assigned the reliability indicator **82** (step **1024**). Once the network switching application **106** updates the geo-fence polygon entry **70**, and the corresponding database **116**, the process returns to step **1004**.

When any wireless communications device **20** travels into an area where the corresponding geo-fence polygon entry **70** includes only information related to a 3G cellular network **30**, and there is a reliable 4G network **40** accessible within the geo-fence polygon **75**, the network switching application **106**, in combination with information obtained from the cellular modem **102**, may update the geo-fence polygon entry **70** (step **1024**) to include information about the 4G cellular network **40**, as shown in FIG. **5**. At this point in time, the network switching application **106** and the cellular modem **102** have determined that there is a reliable 4G cellular network **40** that is not represented as a reliable network in corresponding geo-fence polygon entry **70** (steps **1004**, **1020** and **1022**). The network switching application **106** will determine whether or not the 4G cellular network **40** is represented in the polygon entry **70** (step **1030**). If the 4G cellular network **40** is represented in the geo-fence polygon entry **70**, the network switching application **106** will simply update the geo-fence polygon entry **70** by applying the reliability indicator **82** to the 4G cellular network **40**. If there is no corresponding 4G cellular network **40** information within the geo-fence polygon entry **70**, the network switching application **106** obtains the needed information (4G cellular network **40**, carrier **77**, reliability data **80**) gathered by the cellular modem **102** and enters the information into the geo-fence polygon entry **70** (step **1034**) stored in the database **116** of the storage system **114** or system memory **108** of the wireless communication device **20**. After both steps **1032** and **1034**, the network switching application **106** returns to step **1004**.

In embodiments in which the cellular modem **102** is capable of communicating on multiple 3G cellular networks **30** or 4G cellular networks **40**, the network switching application **106** can determine if another 3G network **30** or 4G network **40** is available when the 3G cellular network **30** or 4G cellular network **40** to which the modem **102** is already

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connected is not reliable (step **1020**), as shown in FIG. **4a**. If the cellular modem **102** is connected to a 4G cellular network **40**, the cellular modem **102** will determine whether or not the 4G cellular network **40** is reliable (step **1050**).

If the 4G cellular network **40** to which the cellular modem **102** is connected is reliable, the cellular modem **102** will return to step **1022** as described above. If the 4G cellular network **40** is not reliable, the network switching application **106** will check to see if another 4G cellular network **40** is available (step **1052**). The network switching application **106** can call on the cellular modem **102** to determine whether or not another 4G cellular network **40** is available. The modem **102** will drop its connection to the current 4G cellular network **40** to search for another 4G cellular network **40**. If the cellular modem **102** finds another 4G cellular network **40**, the network switching application **106** will direct the cellular modem **102** to connect to the newly found 4G cellular network **40** (step **1054**), after which the network switching application **106** will call on the cellular modem **102** to find out if the 4G cellular network **40** is reliable (step **1050**). If the cellular modem **106** finds no other 4G cellular network **40** available, the modem **106** will drop the 4G cellular connection, and will connect to the 3G cellular network **30** (step **1012**). While the method and steps above mention switching between two 4G cellular networks **40**, the method and steps are equally applicable to switching between 3G cellular networks **30** of different carriers, and any other equivalent network carried by different carriers.

The process **1000** above is constantly repeated by the network switching application **106**, comparing the location of the wireless communication device **20** and the current connection of the cellular modem **102**, and all information generated from such a connection, to the corresponding geo-fence polygon entry **70**. The analysis is done on a continuous loop regardless of whether the wireless communication device **20** is stationary or moving. For the most part, the process will continue to return to step **1004**, unless the cellular modem **102** experiences a drop or "quiet time", at which point the process will return to step **1002**.

Having thus described an exemplary embodiment of the operation of the network switching application **106**, those skilled in the art will appreciate that the steps above may be performed in a different order or combination.

The constant monitoring, reporting, and updating of cellular networks performed by the combination of the cellular modem **102** and the network switching application **106** allows the geo-fence polygon entries **70** within the database **116** to be updated to reflect the availability of a reliable 3G and 4G cellular networks **30**, **40** for the corresponding geo-fence polygon **75**. The process makes the network reliability database **116** self-healing. When implemented by multiple wireless communication devices **20** that continuously report the updated entries **70**/database **116** to a central server **60**, the process leverages "crowd sourcing". The first wireless communications device **20** to sense a 4G cellular network **40** within a geo-fence polygon **75** that was previously formerly designated as a part of a 3G cellular service area **35** will update the corresponding geo-fence polygon entry **70** to reflect the new discovery and report the change to the central server **60**. Then all other wireless communications devices **20** will receive the updated geo-fence polygon entry **70** identifying the new availability of 4G cellular network **40** in the corresponding geo-fence polygon **75**.

In all cases the network switching application **106** will continuously perform this programming loop of checking for reliable connectivity to 4G cellular networks **40**, as the vehicle is traveling in and out of 4G service area polygons/

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grid cells. The continuous checking and reporting of various 3G and 4G cellular connectivity quality factors, automatically updating actual cellular connectivity metrics for various geo-fence polygons 75 and corresponding entries 70, provides the ability for the network switching application 106 to maximize 4G connectivity while a wireless communication device 20 is in motion across various cellular coverage areas 35/45. The maximization of 4G cellular network connectivity is maximized further when the process above is employed by numerous wireless communication devices 20 of a fleet, which can report findings to the central server 60, discussed below.

According to some embodiments of the present invention, the network switching application 106 looks ahead for the potential networks that the wireless communication devices 20 will enter to assist in maintaining, dropping, or initiating cellular connections with 3G and 4G cellular networks 30, 40. FIG. 6 depicts a flow diagram 2000 that illustrates the look ahead operation of the network switching application 106 according to one such embodiment of the present invention. The network switching application 106 first determines whether or not the wireless communication device is moving (step 2010). The network switching application 106 can call on the GPS module 128 for such information (e.g., speed, direction, etc.). If the network switching application 106 determines that the wireless communication device 20 is not moving, the network switching application 106 can exit the look ahead process (step 2020) and perform other processes or continue to monitor for its movement.

If the wireless communication device 20 is moving, the network switching application 106 will then determine the relevant geo-fence polygon entries 70 that the wireless communication device 20 will travel through (step 2030), as shown in FIG. 7. The network switching application 106 will obtain the speed and heading information of the wireless communication device 20 (step 2032). The network switching application 106 can obtain this information directly from the GPS module 128 itself, or obtain other information from the GPS module 128 that will allow the network switching application 106 to calculate the heading and speed. Using the heading and speed, the network switching application 106 can then determine the projected route of travel of the wireless communication device 20 (step 2034) and identify the corresponding geo-fence polygon entries 70 (step 2036). If the wireless communication device 20 does not have corresponding polygon entries 70 stored locally in its storage device 116 or local system memory 108, it can request such entries from another source, such as the central server 60 discussed below.

Returning to FIG. 6, the network switching application 106 can then determine whether switching from one network to another creates a benefit or reward that is greater than a switching threshold (step 2040). If the benefit of switching from one cellular network to another is greater than an established threshold, the network switching application 106 will instruct the cellular modem 102 to drop its current connection and connect to the other network (step 2050). If switching does not create a benefit greater than the threshold, the network switching application 106 will instruct the cellular modem 102 to remain connected or ready for the same connection if a drop occurs (step 2060).

The switching threshold may be based upon certain values that can be compared to corresponding information available to the network switching application 106. For example, the switching threshold may include, but is not limited to, the time connected to a faster cellular network, throughput, packet latency, signal strength and the like or combinations of

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the preceding examples. The switching threshold(s) may be standardized, set up automatically, or manually. The network switching application 106 can utilize more than just one switching threshold.

For example, the switching threshold may be set based upon the minimum amount of time that the wireless communication device 20 will experience a connection to a 4G cellular network 40. The wireless communication device 20, currently connected to a 3G network 30, may have a projected route of travel through a 4G cellular network coverage area 45 for forty seconds before reentering into a 3G cellular network service area 35. In this example, the switching threshold requires that the connection to the 4G cellular network 40 must be for at least thirty five seconds before the network switching application 106 will order the modem 102 to disconnect from the 3G cellular network 30 and connect to the 4G cellular network 40. In such an example, the benefit exceeds the switching threshold (forty seconds to thirty five seconds) (step 2040), so the network switching application 106 will order the cellular modem 102 to disconnect from the 3G cellular network 30 and connect to the 4G cellular network 40 (step 2050).

The network switching application 106 may also take into consideration the restraints of the operations needed to switch from network to network, including the required time for such operations to occur, when making the same benefit determination (step 2040). For example, expounding on the example of the wireless communication device 20 being within a 4G cellular coverage area 45 for forty seconds as discussed above, the network switching application 106 may determine that the time required for switching from the 3G network 30 to the 4G network 40 is ten seconds. The time required to switch only allows the wireless communication device 20 to be connected to the 4G cellular network 40 for thirty seconds. Therefore, the benefit (thirty seconds connected to the 4G cellular network 40) does not exceed the switching threshold (thirty-five seconds) (step 2040). In this case, the network switching application 106 will not allow the wireless communication device to switch from the 3G cellular network 30 to the 4G cellular network 40 (step 2060).

In some embodiments of the present invention, the network switching application 106 may assist in collecting information relating to the reliability of the 4G cellular network 40 and 3G cellular network 30. The networking application 106 may create a record 200 of an event 202 that the cellular modem 102 experiences at different locations within a 3G or 4G cellular network coverage area 35, 45 and for different events. For example, when the wireless communication device 20 is disconnected from a 4G cellular network 40, such as when the wireless communication device 20 exits from a the 4G cellular network coverage area 45, the network switching application 106 can create a record 200 of the drop 202, as shown in FIG. 8. The record 200 can include date information 204, time information 206, location information 208, and signal information 210, including signal strength, throughput, packet drop ratio, and the like, from the GPS module 128 and the cellular modem 102, and from the wireless communication device 20 itself. The network switching application 106 may couple this information with the already established geo-fence polygon/grid cell entry 70 associated with the 4G cellular network geo-fence polygon 75.

The same can be done for a drop within a geo-fence polygon 75 of a 3G cellular network 30. Along the same lines, a record 200 can be created for a status event 202, when the cellular modem 102 remains connected a 4G cellular network 40 or 3G network 30, containing the same information as stated above. Such a record is useful in determining the reli-

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ability of the coverage areas **35**, **45** of the 3G cellular networks **30** and 4G cellular networks **40** at given locations **208** defined by the respective geo-fence polygon **75**. Records **200** can be used to determine whether the geo-fence polygon **75** associated with a 3G or 4G cellular network coverage area **35**, **45** is accurate, or needs to be adjusted.

The network switching application **106** may also create a record **200** when the wireless communication device **20**, through the cellular modem **102**, finds a 4G cellular network **40** that was not previously known. If the cellular modem **102** discovers a new 4G cellular network **40** and determines that the network **40** at those locations is reliable, determined from the signal information **210** collected by the cellular modem **102**, the network switching application **106** can obtain location information **208** from the GPS module **128** and create a record **200** documenting the connection. In such instances, the network switching application **106** will continuously create records **200** while connected and up to the disconnecting of the cellular modem **102** from the newly discovered 4G cellular network **40** to help establish the geo-fence polygons **75** of the 4G cellular network **40** through which the wireless communication device **20** travels. A new geo-fence polygon entry **70** may be made from the records, taking the signal information **210** to determine the reliability data **80** of the newly created geo-fence polygon **75** of the coverage area **45** of the new 4G cellular network **40**.

Similarly, the network switching application **106** can create a record **200** when the cellular modem **102** produces reliable signal information **210** for a 4G cellular network **40** in a geo-fence polygon **75** that was previously is identified as unreliable by the associated reliability data **80** of its geo-fence polygon entry **70**, indicating an improvement of the signal quality in the coverage area **45**.

The network switching application **106** can then utilize the records **202** to maintain and update the geo-fence polygon information **212** that is has retained, maintain, update or create new geo-fence polygon entries **70**, or can send such records to the central server **60**, as discussed below.

As shown in FIGS. 1-2 and 9, the automated cellular network switching system **10** may include a central server **60**. The central server **60** may have several applications **304**, including but not limited to a network geo-fencing management application **308**, discussed in further detail below. The network geo-fencing management application **308** may utilize elements and/or modules of the various applications that may utilize several nodes or servers. In any event, the phrase central server **60** should be construed as inclusive of multiple modules, software applications, and other components that are separate from the wireless communication devices **20**.

Referring to FIG. 9, the central server **60** includes its own system memory **302**, which stores the operating system **304** and various software applications **306**, including the network geo-fencing management application **308**. The central server **60** may also include data **310** that is accessible by the software applications **306**. The remote central server **60** may include a mass storage device **312**. The mass storage device **312** can be used for storing computer code, computer readable instructions, program modules, various databases, including a reliability database **314**, and other data for the server **60**. The mass storage device **312** can be used to back up or alternatively to run the operating system **304** and/or other software applications **302**. The mass storage device **312** may include a hard disk, various magnetic storage devices such as magnetic cassettes or disks, solid state-flash drives, CD-ROM, DVDs or other optical storage, random access memories, and the like.

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The central server **60** may include a system bus **316** that connects various components to the system memory **302** and to the mass storage device **312**, as well as to each other. Other components of the central server **60** may include one or more processors or processing units **318**, a user interface **320**, an input/output interface **322**, and a network adapter **324** that is configured to communicate with other devices over various networks, including, but not limited to cellular networks **30**, **40**. In addition, the central server **60** may include a display adapter **326** that communicates with a display device **328**, such as a computer monitor and other devices that present images and text in various formats.

A system administrator can interact with the network geo-fencing management application **308** and other software applications **306** on the central server **60** through one or more input devices (not shown), which include, but are not limited to, a keyboard, a mouse, a touch-screen, a microphone, a scanner, a joystick, and the like, via the user interface **318**.

In one embodiment of the present invention, the automated cellular network system **10** utilizes the central server **60**, and more specifically the network geo-fencing management application **308** and the reliability database **314**, to communicate, manage, and update the geo-fence polygon entry **70** associated with each geo-fence polygon **75** of the known 3G and 4G cellular networks **30**, **40** for the wireless communication devices **20**.

FIG. 10 depicts a flow diagram **3000** that illustrates the operation of the network geo-fencing management application **308** according to one embodiment of the present invention. The geo-fencing management application **308** will receive records **200** from the wireless communication devices **20** (Step **3100**). As depicted in FIG. 11, the records can be sent over a 3G cellular network **30** or a 4G cellular network **40**, depending on the location of the wireless communication device **20**. The records **200** prepared by the network switching application **106** may be sent out from each wireless device **20** as they are prepared, or the networking switching application **106** may bundle the records **200** together for transmission at regularly scheduled intervals. In some embodiments of the present invention, the network switching application **106** may retain the records **200** on the storage device **114** or system memory **108** until the records can be downloaded to the central server **60** once the wireless communication device **20** returns to base.

Upon receiving the records **200**, the geo-fencing management application **308** can then update the geo-fence polygon entries **70** on its reliability database **314** (step **3200**), shown in more detail in FIG. 12.

Similar to the wireless communication devices **20**, the network geo-fencing management application **308** can update the geo-fence polygon entries **70** as it receives records **200**, at regular intervals, or once the central server **60** has received all of the records **200** produced by the wireless communication devices for a given day. The network geo-fencing management application **308** will examine the records **200** to find a corresponding geo-fence polygon entry **70** within the database **314** (step **3210**). If a corresponding entry **70** is found, the network geo-fencing management application **308** will update the geo-fence polygon entry **70**, including the reliability data **80** and reliability indicator **82** based upon the location **208** signal information **210** received in the database **314** (step **3220**). If a corresponding entry is not found, the network geo-fencing management application **308** will create a new geo-fence polygon entry **70** within the database **314**, using the location information (**3230**).

In some embodiments of the present invention, the network geo-fencing management application **308** may receive

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updated geo-fence polygon entries **70** directly from the wireless communication devices **20** in addition to records **200**. The process described in FIG. **11** may be done with update geo-fence polygon entries **70** obtained directly from the wireless communication devices **20**.

While the network geo-fencing management application **308** can update the geo-fence polygon entries **70** at a variety of times, it is preferable that the updates occur as new records **200** are received, creating an up-to-date database **314**. In addition, all the changes to the records **200** may be logged in order to allow the network geo-fencing management application **308** to review and find patterns of the quality of the 3G and 4G cellular networks **30**, **40** in the various geo-fence polygons **75** at various times throughout the day. In some embodiments of the present invention, the network geo-fencing management application **308** can use past data to predict the performance of a network at a given location at a given time and pass that information along to the wireless communication devices **20**.

Returning to FIG. **11**, once the geo-fence polygon entries **70** are updated, the network geo-fencing management application **308** will then make the updated geo-fence polygon entries **70** available to the wireless communication devices **20** (step **3300**). The present invention encompasses both local database storage and real-time data lookup techniques to provide information about reliable 3G and 4G cellular coverage areas **35**, **45** and their corresponding geo-fence polygons **75** for the wireless communication devices **20**. In one embodiment of the present invention, the network geo-fencing management application **308** will transmit the updated geo-fence polygon entries **70** to wireless communication device **20**, with the network switching application **108** assisting in updating the database **116** with such information. Such updates can be sent on a periodic basis, or can be downloaded to the wireless communication devices **20** at the beginning of the shift. In some embodiments of the present invention, the wireless communication devices **20** include a globally unique serial number and other unique identifiers, such as MAC addresses, which allow the central server **60** to track and report on the wireless communication devices **20** based upon their unique identifiers.

In another embodiment of the present invention, the wireless communication devices **20** can request a real-time lookup of the updated geo-fence polygon entries **70** from the central server **60**. However, periodically updating the database **116** of the wireless communication device **20** will often eliminate the need for the data transmission overhead of real-time lookups of reliable 4G geo-fence polygons **75**. In this instance the network switching application **108**, via the cellular modem **102**, would continuously make real-time database requests to the network geo-fencing management application **308** on the central server **60** to download geo-entry polygon entries **70** for adjacent geo-fence polygons **75** around the current geo-fence polygon **75** in which the vehicle/wireless cellular device **20** is located. The adjacent geo-entry polygon entries **70** could be kept in RAM memory and not stored in the local database **116** of wireless communication device **20** and yet still provide the capability to determine when to switch cellular communications from 3G mode to 4G mode.

In another embodiment of the present invention, a hybrid combination of local database storage of and real-time requests for geo-fence polygon entries **70** can occur. For example, the database **116** of a wireless communication device **20** may only have geo-fence polygon entries **70** for a particular region (e.g., the metro Atlanta, the state of Pennsylvania, USA, a diameter of 25 miles around the vehicle's

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home service center, or another definition of region are all possible examples). When the wireless communication device **20** travels outside of its particular region, the network switching application **106** may request real-time downloads for geo-fence polygon entries **70** located in the direction of the current heading. Such downloads may be stored on the local database **116** or within the system memory **106**.

It is anticipated that the cellular modems **102** of the present invention will be provided by and linked to a number of public wireless network providers such as AT&T, Sprint, and Verizon, and also for a number of private wireless network providers such as the Public Safety Broadband Network, New York City NYCWIN network, and other private 4G and 3G wireless communications networks around the world. The network reliability database **314** of the central server **60** will capture and categorize network reliability data records for each network, and can make 4G polygon network reliability data available to all users and customers of each type of public and private wireless network. So customers using cellular modem **102** provided by a public or private wireless network provider could have the benefit of network reliability data from all other users of a carrier's cellular modem **102** who are also reporting data to the central server's reliability database **314**.

Embodiments of the automated cellular network switching systems **10** that utilize a central server **60** to maintain updated records regarding reliable 4G cellular coverage areas **45** are especially valuable to businesses dependent on fleets of vehicles for their business operations. The collective reporting power of the vehicles enhances the operation of the network switching applications **106** by having updated geo-fence polygon information. The larger the fleet, the more effective the automated cellular network switching system **10** becomes.

Further, reliable 4G cellular coverage geo-fence polygon information can also be shared across multiple enterprise fleets. As a result, reliable 4G cellular coverage geo-fence polygon entries **70** collected by the vehicle fleet of one enterprise that is part of the same automated cellular network switching system **10** can be shared and leveraged by vehicle fleets of other enterprises within the same system **10**. Collecting and sharing reliable 4G cellular coverage geo-fence polygon entries **70** with wireless communication devices **20** in multiple enterprises will provide more effective and accurate "crowd source" reporting reliable 4G cellular coverage geo-fence polygon entries **70** than could be achieved by vehicles in a single enterprise alone.

The advantages of the present invention include, without limitation, providing field personnel who are using cellular data communications while operating a vehicle with the ability to maximize the use of higher 4G bandwidth to more safely, efficiently, and effectively do their work. The vehicle driver does not have to be concerned with knowing on a second by second basis whether the vehicle, and the wireless communication device **20**, is in 3G or 4G network coverage areas. Furthermore, the vehicle driver is not distracted by having to attempt to manually maintain a fast 4G cellular data communications connection. This is particularly the case when the wireless communication device **20** does not have a keyboard and screen, like a wireless router, and it is not practical for the driver to manually restart the wireless communication device **20** to force an initial connection attempt to connect to a 4G cellular network **40**.

Further, embodiments of the present invention are capable of collecting and reporting current reliable 4G cellular coverage geo-fence polygon information, without the driver in the vehicle having to provide any manual input or otherwise

be engaged in connection drops and discovery of 4G cellular networks. Having automatic fact-based reporting of the exact location and date/time of 4G cellular connection drops and discovery will help maximize the utilization of 4G coverage when a vehicle is within the boundaries of a 4G coverage area. The location of actual 4G coverage drops can also be shared with the cellular carriers to assist them in filling in 4G coverage gaps and generally improving the quality—availability and reliability—of 4G cellular coverage in the areas where the vehicle driver with the wireless communication device travels in the course of his service delivery and/or public safety work. Automatic discovery of new 4G cellular coverage geo-zone polygons allows the enterprise to use higher bandwidth 4G connectivity whenever it becomes available, regardless of whether the new 4G coverage has been reported by the cell carrier.

To the extent necessary to understand or complete the disclosure of the present invention, all publications, patents, and patent applications mentioned herein are expressly incorporated by reference therein to the same extent as though each were individually so incorporated.

Having thus described exemplary embodiments of the present invention, those skilled in the art will appreciate that the within disclosures are exemplary only and that various other alternatives, adaptations, and modifications may be made within the scope of the present invention. Accordingly, the present invention is not limited to the specific embodiments as illustrated herein, but is only limited by the following claims.

What is claimed is:

1. An automated cellular network switching system comprising:

- a) a plurality of wireless communication devices, wherein each of the plurality of wireless communication devices comprises:
 - i) a cellular modem configured to communicate on at least two 3G cellular networks or at least two 4G cellular networks;
 - ii) data storage comprising a database configured to store geo-fence polygon entries, wherein each geo-fence polygon entry is associated with a geo-fence polygon that includes information related to each 3G cellular network and 4G cellular network known to operate within borders of the geo-fence polygon;
 - iii) a network switching application associated with a processor configured to:
 - (A) automatically control the connection of the cellular modem to one of the at least two 3G cellular networks or the at least two 4G cellular networks available within the geo-fence polygon in which the wireless communication device is located based upon the information within the corresponding geo-fence polygon entry; and
 - (B) generate records of connection events of the cellular modem;
- b) a central server comprising:
 - i) a database configured to store geo-fence polygon entries; and
 - ii) a network geo-fencing management application, wherein the network geo-fencing management application is configured to:
 - (A) receive the records of connection events from the plurality of wireless communication devices;
 - (B) manage and update the database of the geo-fence polygon entries; and
 - (C) send updated geo-fence polygon entries to the plurality of wireless communication devices.

2. The automated cellular network switching system of claim 1, wherein the geo-fence polygon entry comprises:

- a) a geo-fence polygon identifier;
- b) coordinates of the geo-fence polygon identifier;
- c) carrier identifiers for each cellular network operating within the coordinates of the geo-fence polygon;
- d) for each cellular network known operating within the geo-fence polygon, a 3G cellular network identifier and, if present, a 4G cellular network identifier;
- e) reliability data for each cellular network identified within the geo-fence polygon; and
- f) a reliability indicator assigned to the 3G cellular network or the 4G cellular network located within the geo-fence polygon for each carrier, whichever one is deemed to be the most reliable.

3. An automated cellular network switching system comprising:

- a) a plurality of wireless communication devices, wherein each of the plurality of wireless communication devices comprises:
 - i) a cellular modem configured to communicate on at least one 3G cellular network and at least one 4G cellular network;
 - ii) data storage comprising a database configured to store geo-fence polygon entries, wherein each geo-fence polygon entry is associated with a geo-fence polygon that includes information related to each 4G cellular network and 3G cellular network known to operate within borders of the geo-fence polygon;
 - iii) a network switching application associated with a processor configured to:
 - (A) automatically control the connection of the cellular modem to the 4G cellular network or the 3G cellular network available within the geo-fence polygon in which the wireless communication device is located based upon the information within the corresponding geo-fence polygon entry; and
 - (B) generate records of connection events of the cellular modem;
- b) a central server comprising:
 - i) a database configured to store geo-fence polygon entries; and
 - ii) a network geo-fencing management application, wherein the network geo-fencing management application is configured to:
 - (A) receive the records of connection events from the plurality of wireless communication devices;
 - (B) manage and update the database of the geo-fence polygon entries; and
 - (C) send updated geo-fence polygon entries to the plurality of wireless communication devices.

4. The automated cellular network switching system of claim 3, wherein the geo-fence polygon entry comprises:

- a) a geo-fence polygon identifier;
- b) coordinates of the geo-fence polygon identifier;
- c) carrier identifiers for each cellular network operating within the coordinates of the geo-fence polygon;
- d) for each cellular network known operating within the geo-fence polygon, a 3G cellular network identifier and, if present, a 4G cellular network identifier;
- e) reliability data for each cellular network identified within the geo-fence polygon; and
- f) a reliability indicator assigned to the 3G cellular network or the 4G cellular network located within the geo-fence polygon for each carrier, whichever one is deemed to be the most reliable.

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5. The automated cellular network switching system of claim 4, wherein the network switching application generates the records of connection events from signal information and location information obtained by at least one of the plurality of wireless communication devices.

6. The automated cellular network switching system of claim 5, wherein at least one of the plurality of wireless communication devices further comprises a GPS module, the GPS module configured to supply the network switching application with the location information.

7. The automated cellular network switching system of claim 5, wherein the cellular modem of at least one of the plurality of wireless communication devices is further configured to supply the network switching application with the signal information, wherein the signal information comprises signal strength, signal quality, and signal availability.

8. The automated cellular network switching system of claim 4, wherein at least one of the records of connection events comprises:

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a) an event type;

b) location information;

c) signal information; and

d) the geo-fence polygon entry, if any, that corresponds to the location information.

9. The automated cellular network switching system of claim 5, wherein the network geo-fencing management application is configured to manage and update the database of geo-fence polygon entries by matching the records of connection events to corresponding geo-fence polygon entries, updating a geo-fence polygon and reliability data of the corresponding geo-fence polygon entry based upon the signal information and location information of the corresponding record of connection event, and creating a new geo-fence polygon entry if no corresponding geo-polygon entry is found or provided from at least one record, wherein the new geo-fence polygon entry is formed from the at least one record.

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