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(54) **PICO-CELL EXTENSION FOR CELLULAR NETWORK**

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370/338

(58) **Field of Classification Search** **455/431,**
455/444, 445; 370/338; 378/338
See application file for complete search history.

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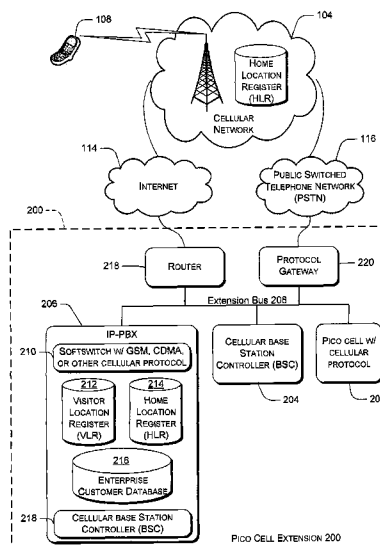
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(57) **ABSTRACT**

A pico-cell is located within a facility. The pico-cell has a wireless protocol for carrying calls placed to and from mobile devices in the facility. A call distributor is in communication with the pico-cell and handles calls carried by the pico-cell. The call distributor includes an embedded wireless switch for routing calls to and from mobile devices in the facility using the wireless protocol.

12 Claims, 8 Drawing Sheets



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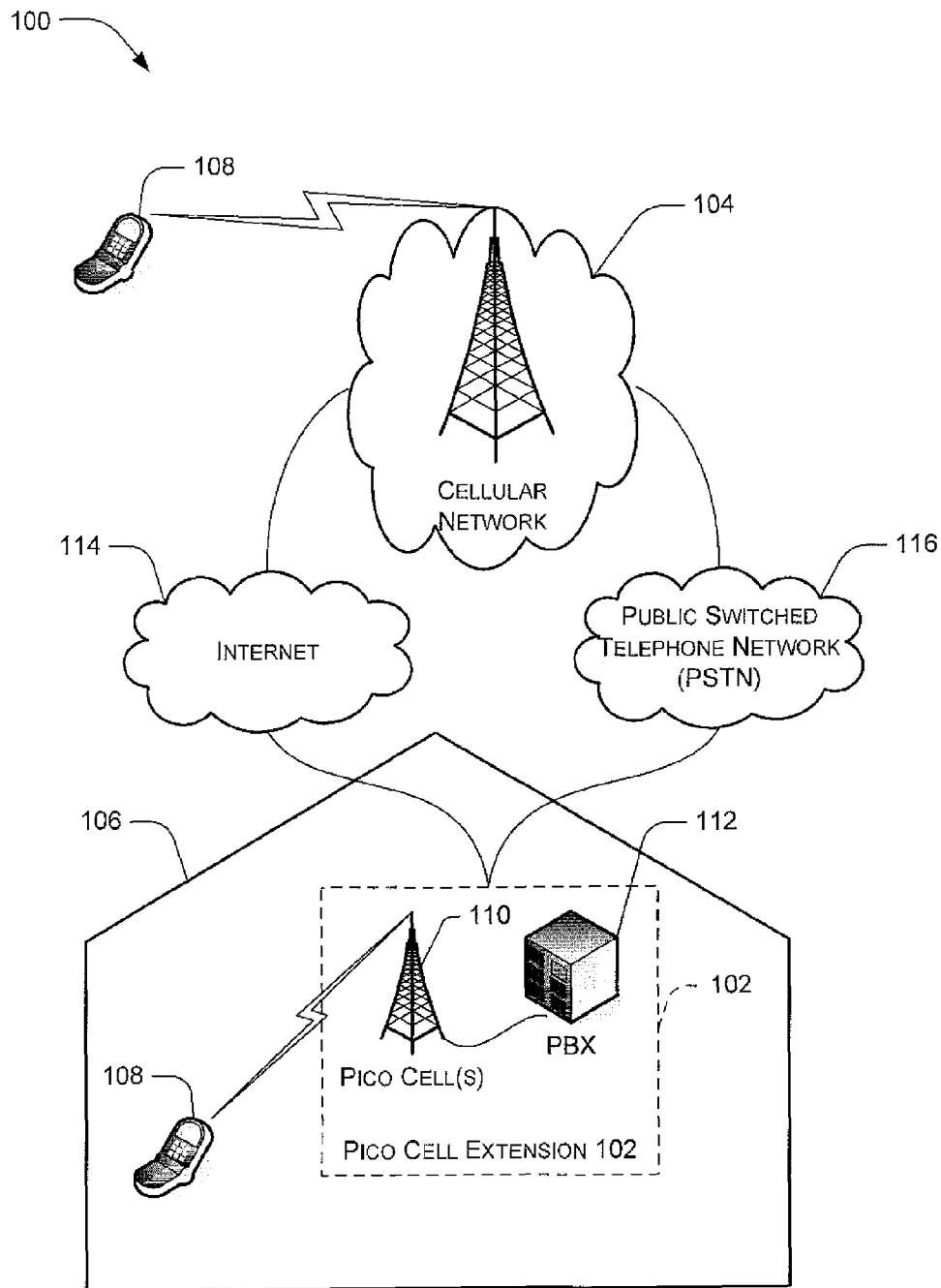


FIG. 1

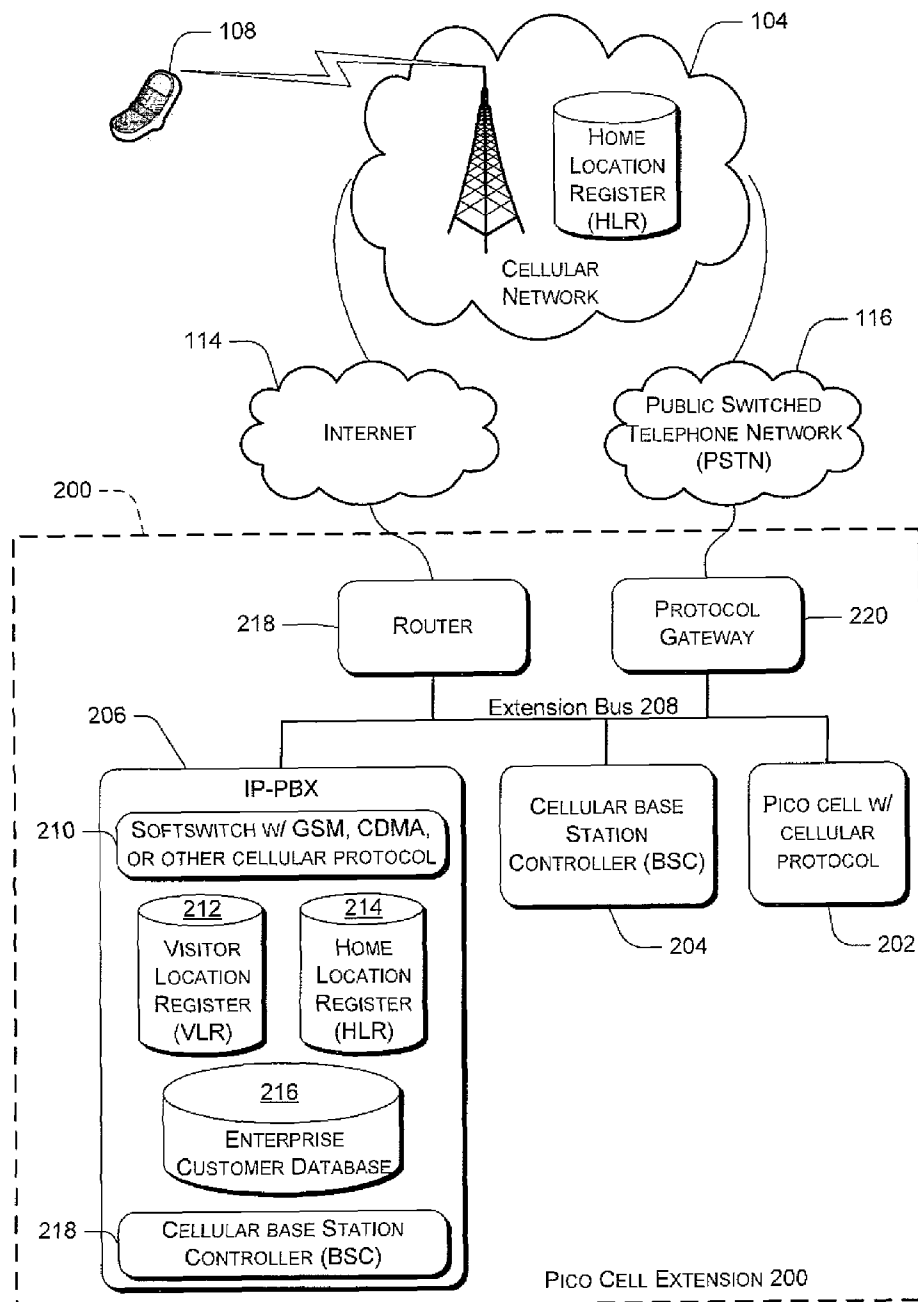


FIG. 2

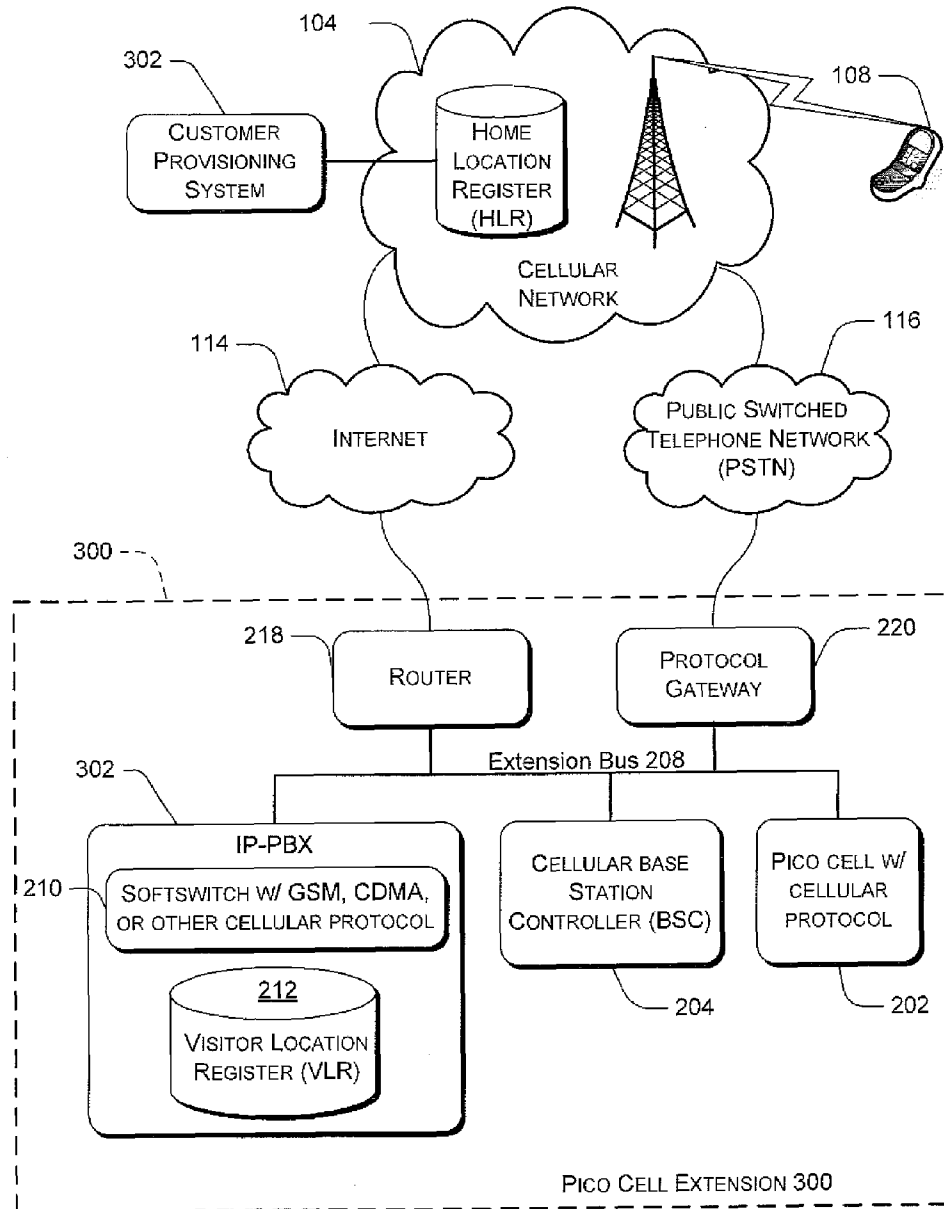


FIG. 3

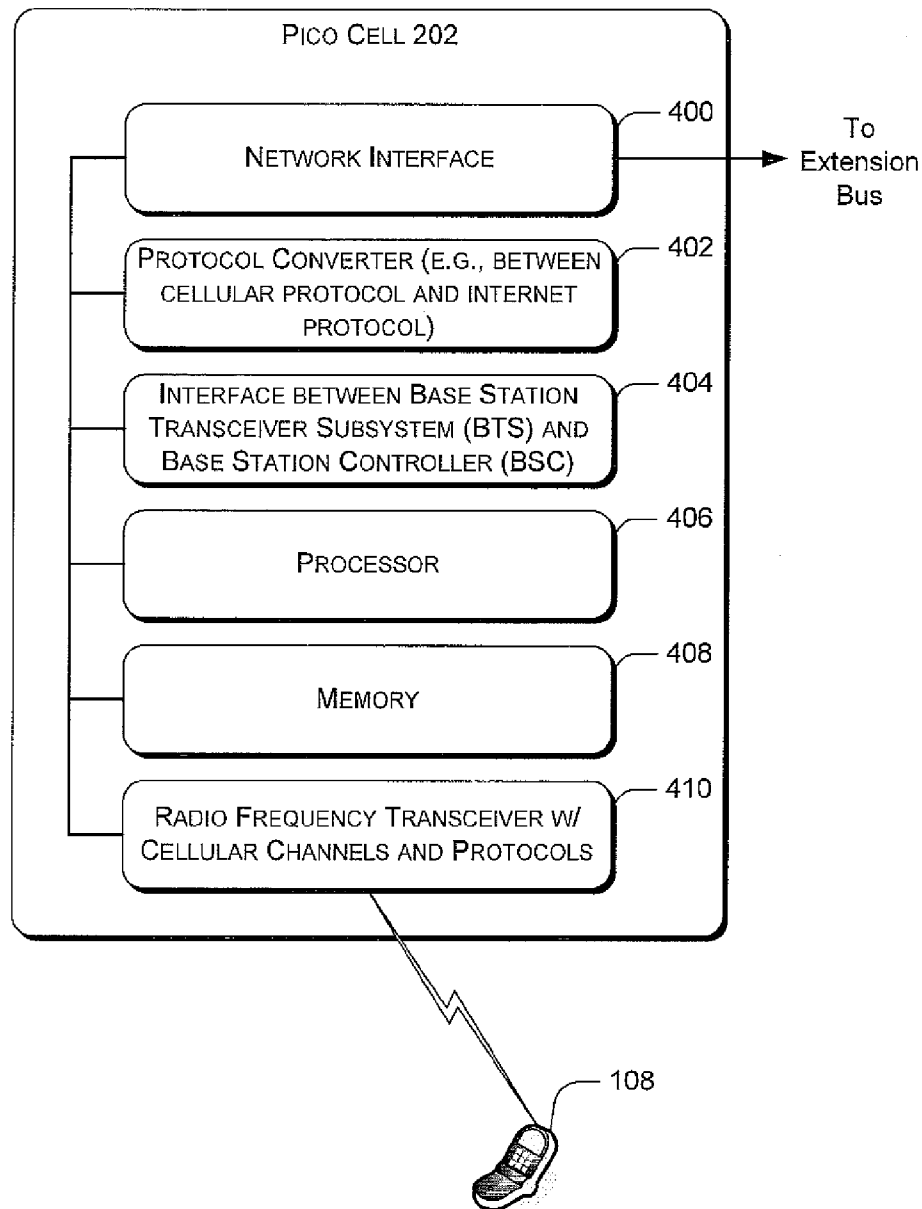


FIG. 4

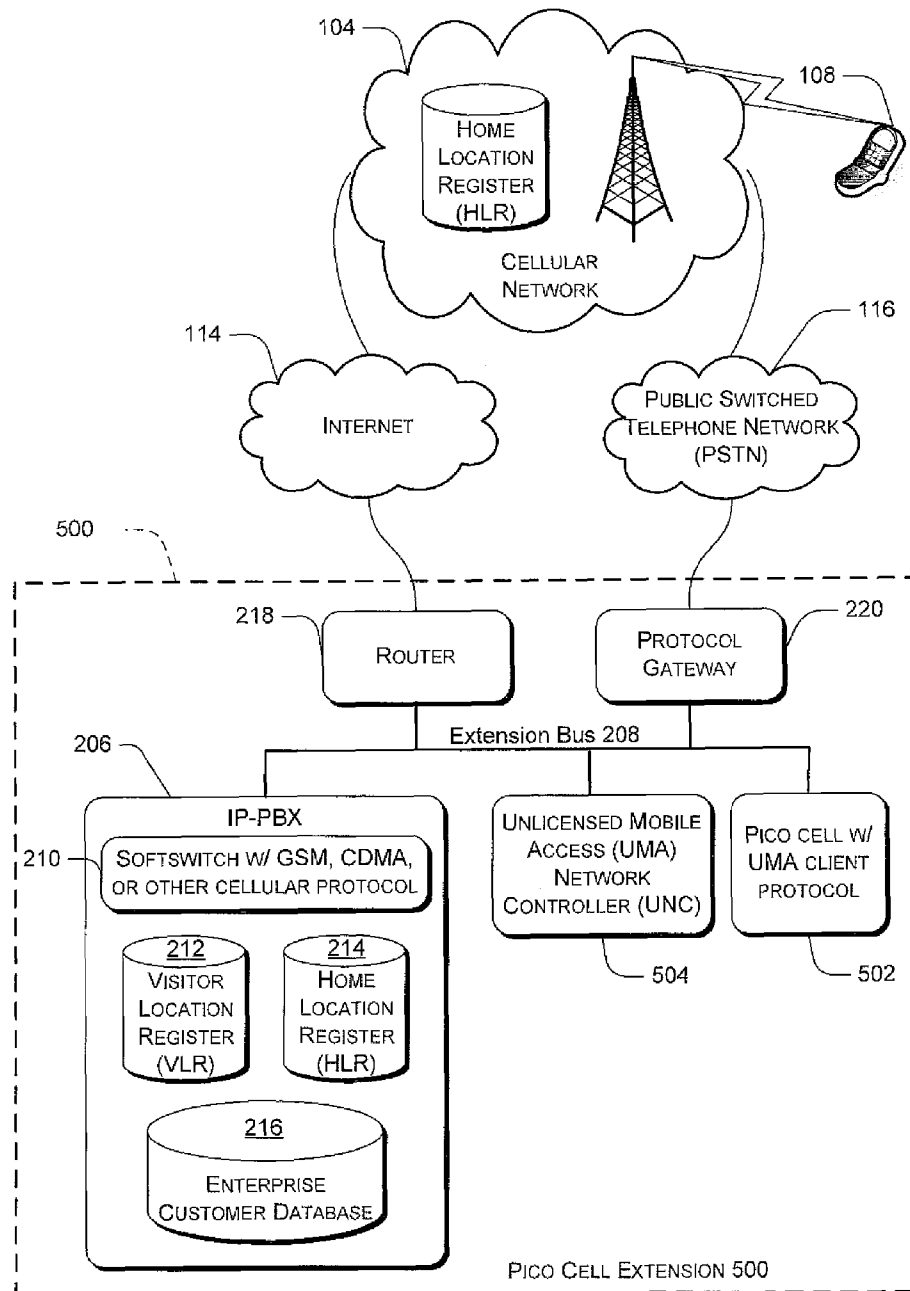


FIG. 5

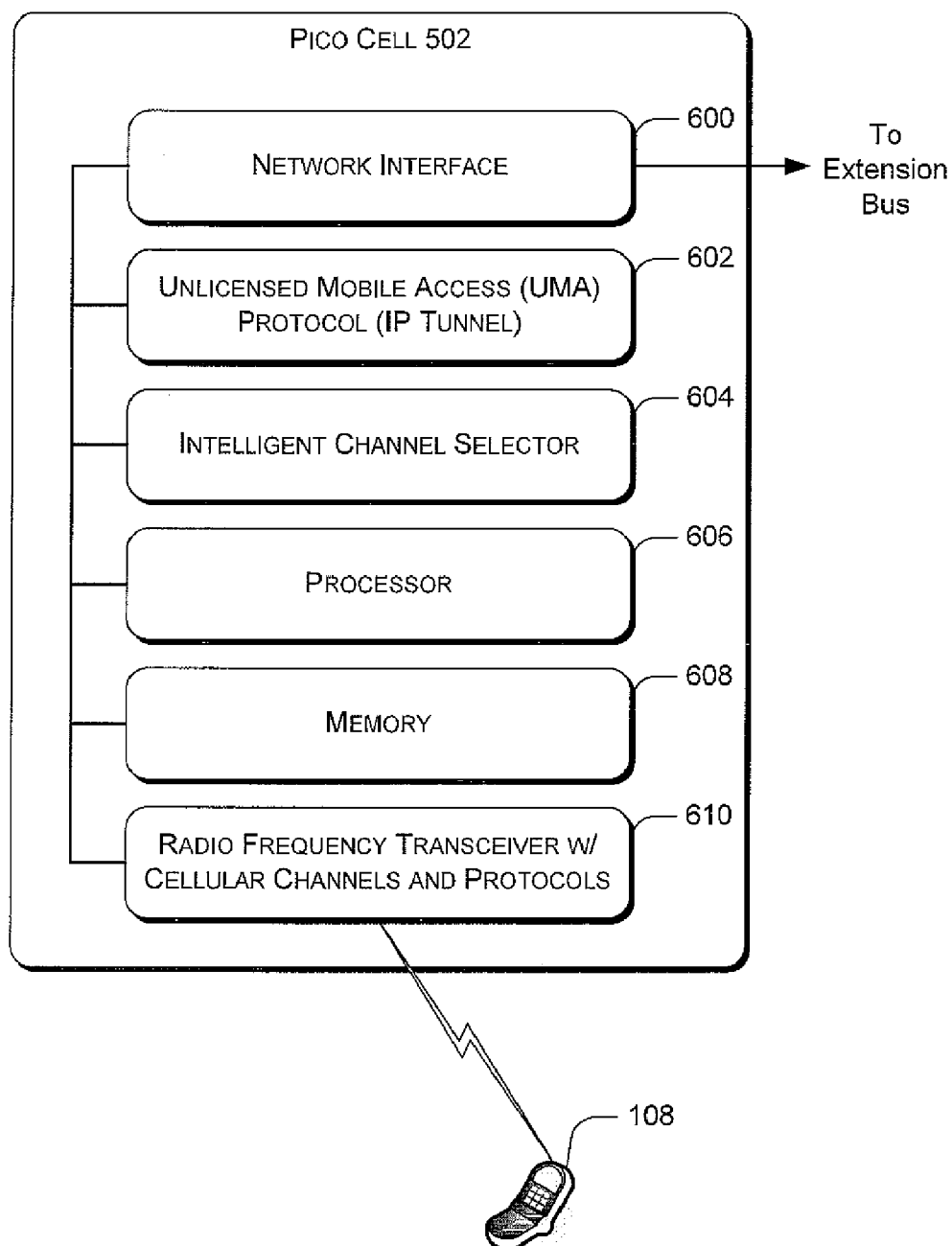


FIG. 6

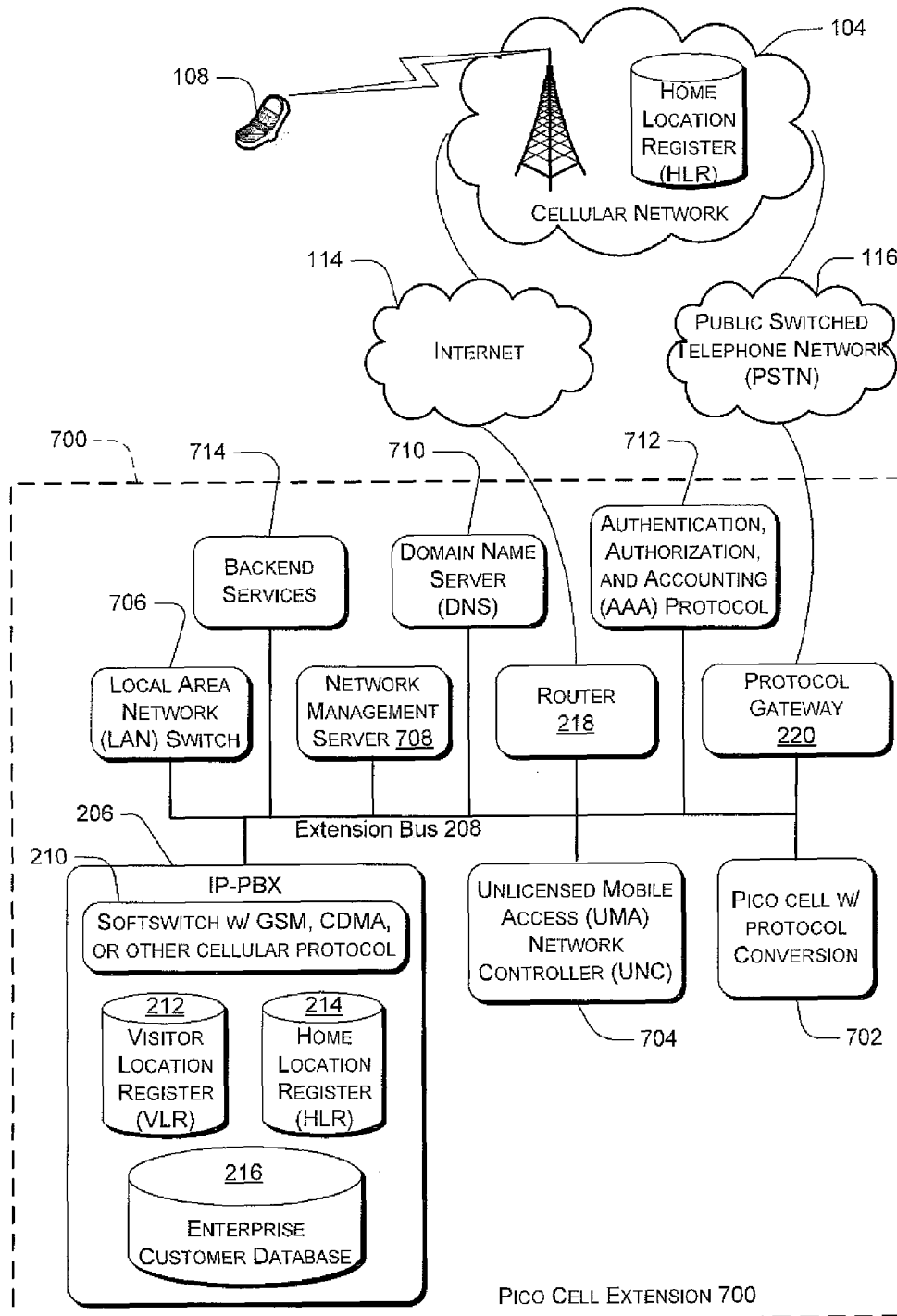


FIG. 7

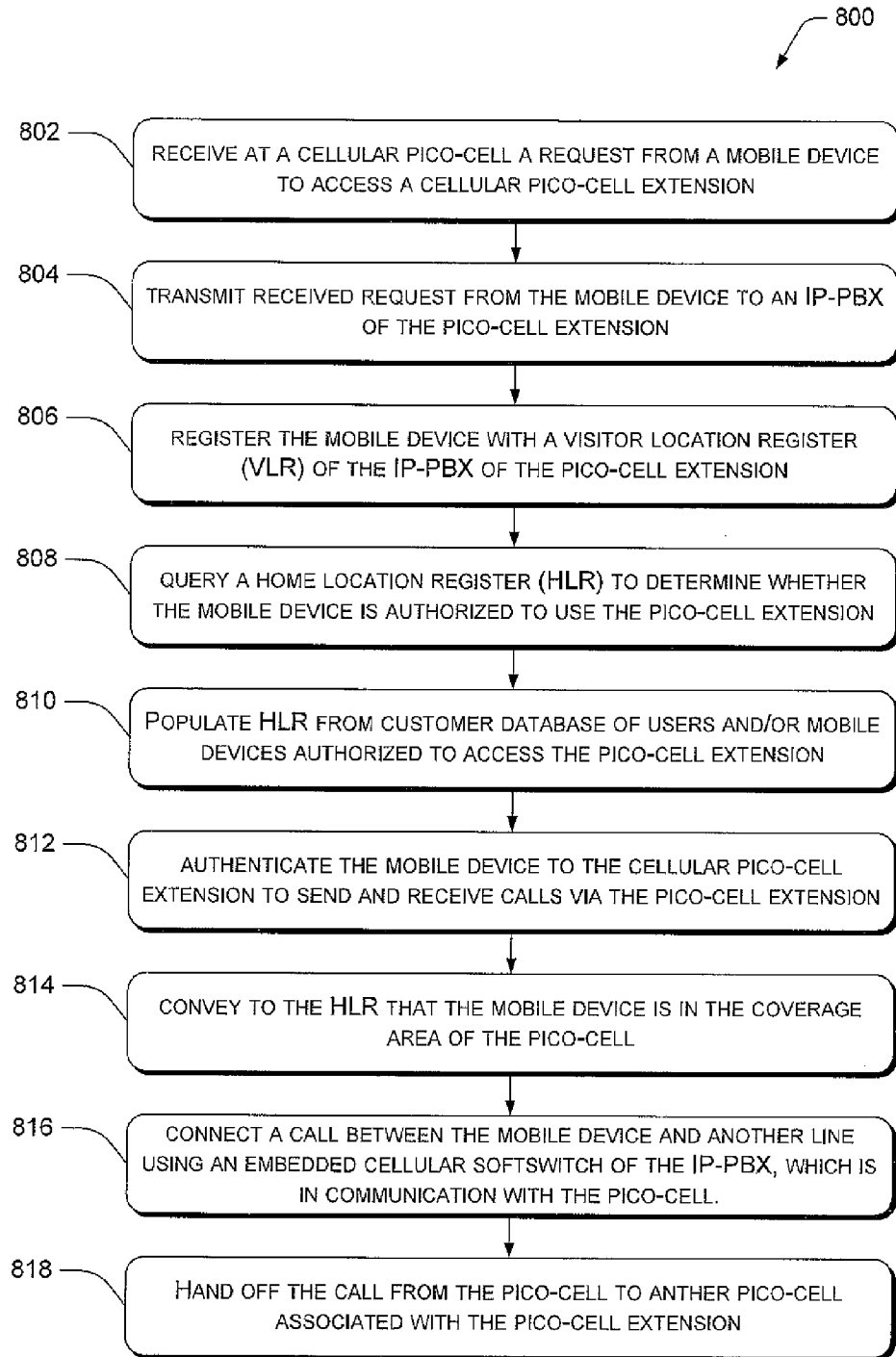


FIG. 8

1

PICO-CELL EXTENSION FOR CELLULAR NETWORK

BACKGROUND

Enterprises want wireless communications for their employees within their work place (office buildings and warehouses, retail facilities, etc) and in the field. Cell phones are satisfactorily used by employees for wide area mobile communications, but coverage within buildings is not always adequate. Coverage problems arise when a user attempts to use a cell phone inside a building. For example, electromagnetic signals, such as radio frequencies used by cellular phones, are unable to fully propagate through walls, metalized glass and other common building materials that separate the inside of a building from an outside environment. As a result, the user may experience a degradation of service or may be precluded entirely from sending or receiving information while inside a building or other structure.

One solution to poor in-building cellular coverage has been to install a wireless private branch exchange (PBX) and to issue employees wireless WiFi enabled session initiated protocol (SIP) phones for mobile communications within buildings. However, this requires the enterprise to purchase two mobile devices for each employee—a cell phone for wide area communication, and a WiFi SIP phone for communication within the work place—which may be a substantial expense. In addition, this requires employees to carry multiple mobile devices, each typically having different contact number associated with it. Thus, callers must dial a different number to reach the employee, depending on the location of the employee (e.g., in the work place or in the field).

SUMMARY

This summary is provided to introduce simplified concepts of a pico-cell extension for a cellular network, which is further described below in the Detailed Description. This summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

In one implementation, a pico-cell is located within a facility. The pico-cell has a wireless protocol for carrying calls placed to and from mobile devices in the facility. A call distributor is in communication with the pico-cell and handles calls carried by the pico-cell. The call distributor includes an embedded wireless switch for routing calls to and from mobile devices in the facility using the wireless protocol.

In another implementation, a wireless pico-cell receives a request from a mobile device using a wireless protocol to access a wireless pico-cell extension. The request from the mobile device is transmitted to a call distributor of the pico-cell extension. The mobile device is registered with a registered visitor database of the call distributor of the pico-cell extension, and the pico-cell extension authenticates the mobile device to send and receive communications via the pico-cell extension.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items.

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FIG. 1 is a schematic diagram showing an exemplary environment, in which a pico-cell extension is coupled to a wireless network to extend wireless coverage within a building.

FIG. 2 is a block diagram showing details of an exemplary implementation of a pico-cell extension for a wireless network.

FIG. 3 is a block diagram showing details of another exemplary implementation of a pico-cell extension for a wireless network.

FIG. 4 is a block diagram showing the pico-cell of FIGS. 2 and 3 in more detail.

FIG. 5 is a block diagram showing details of another exemplary implementation of a pico-cell extension for a wireless network.

FIG. 6 is a block diagram showing the pico-cell of FIG. 4 in more detail.

FIG. 7 is a block diagram showing details of yet another exemplary implementation of a pico-cell extension for a wireless network.

FIG. 8 is a flow chart showing an exemplary method of providing wireless coverage within a facility.

DETAILED DESCRIPTION

Overview

FIG. 1 shows an exemplary environment **100**, in which a pico-cell extension **102** is coupled to a wireless network, e.g., a cellular network **104** to extend and facilitate cellular coverage within a building **106**, factory, warehouse, or other facility of an enterprise. Although a cellular network **104** and a cellular pico-cell extension **102** are shown and described in the following for ease of explanation, it should be appreciated that the invention is applicable to any type of wireless network and wireless pico-cell extension.

As shown in FIG. 1, in the field, a mobile device **108** is in wireless communication with the cellular network **104** via one or more cell towers in a known manner. The cellular network **104** may be based on the global system for mobile communications (GSM), code division multiple access (CDMA), and/or any other cellular protocol. Within the building **106**, however, communication directly between the mobile device **108** and the cellular network may be limited or nonexistent. The pico-cell extension **102** uses cellular protocol and provides reception for the mobile device **108** within the building **106**. In this way, employees of the enterprise or other users of the mobile devices **108** can use the same mobile device **108** in the field via the cellular network **104**, and inside the enterprise facilities via the pico-cells extension(s) **102**. Thus, the pico-cell extension **102** acts like an extension of the cellular network **104** within a structure, and provides or enhances cellular coverage within the structure.

Generally, the pico-cell extension **102** comprises one or more pico-cells **110** in communication with a call distributor, such as a private branch exchange (PBX) **112**, and is connected to the cellular network **104** via the Internet **114** and/or the public switched telephone network (PSTN) **116**. Additionally, the pico-cell extension **102** may include various other network components such as servers, local area network (LAN) switches, routers, memory, and processors, as described in more detail with respect to FIGS. 2-6 below. Pico-cells **110** approximate traditional cellular base stations, but are typically smaller and less powerful than a traditional cellular base station for serving smaller areas, such as buildings or portions thereof. The size and power of pico-cells **110** may vary depending on the desired coverage area and other needs of the enterprise. Examples of pico-cells usable with the pico-cell extensions include those described in U.S.

patent application Ser. No. 11/276,269, filed Feb. 21, 2006, and entitled "Intelligent Pico-Cell for Transport of Mobile Device Communications Over Wireless Networks," now U.S. Pat. No. 7,623,857, which is incorporated herein by reference.

While the pico-cell extension **102** is shown comprising a single pico-cell **110** located within a single building **106**, pico-cell extensions may in some implementations include plural pico-cells located in different rooms of a building, different locations within a room, and/or different buildings. Also, while a single PBX is shown, additional PBXs could be networked together to any number of one or more pico-cells, depending on the needs and resources of the enterprise.

In the exemplary implementations described herein, mobile devices **108** comprise cell phones and the pico-cells **110** comprise cellular pico-cells using the GSM protocol. However, mobile devices **108** could alternately comprise a variety of other types of computer and computer-like devices, such as, for example, Smartphones, tablet PCs, personal digital assistants (PDAs), workstations, or the like, which can transmit and/or receive voice, data, or a combination of voice and data. The pico-cells **110** may comprise pico-cells employing any cellular protocol capable of operating in conjunction with the mobile devices **108**. Since the pico-cell extension **102** employs a cellular protocol, no inclusion of a bulky and/or costly client device in the mobile devices **108** is necessary to enable the mobile devices **108** to communicate with the pico-cell extension **102**.

First Exemplary Pico-Cell Extension

FIG. 2 is a block diagram showing details of an exemplary implementation of a pico-cell extension **200** that might be used to improve wireless coverage in, for example, a facility of an enterprise. The pico-cell extension **200** includes one or more pico-cells **202**, a base station controller (BSC) **204**, and a PBX **206** coupled together by a local area network (LAN) or extension bus **208**. The pico-cells **202** operate at cellular frequencies (these may vary from country to country) and include cellular protocols, such as GSM, CDMA, and the like. The pico cell extension **200** acts as a small extension of the cellular network **104** within the enterprise facility, and carries calls placed to and from mobile devices **108** in the facility in much the same way as a conventional macro cellular base station of the cellular network **104**. That is, the pico cell extension **200** handles calls among mobile devices **108** in the facility, and between mobile devices **108** in the facility and mobile devices and/or wireline phones outside the facility.

The pico-cells **202** are connected to the other components on the extension bus **208** through an Internet protocol security (IPSEC) tunnel. The pico-cells **202** and other components of the pico-cell extension **200** may be connected to the extension bus **208** via an Ethernet port or any other conventional network connection, such as via a broadband modem, or the like.

The BSC **204** acts as a concentrator into which the pico-cells **202** attached to the pico-cell extension **200** are aggregated. The BSC **204** handles allocation of radio channels, receives measurements from the mobile phones, and/or controls handovers among the pico-cells **202** and between the pico-cells **202** and the cellular network **104**. The BSC **204** may also include a database containing information about the pico-cells **202** that it controls, such as carrier frequencies, frequency hopping lists, power reduction levels, receiving levels for pico-cell border calculations, and the like.

In this implementation, the PBX **206** comprises an Internet protocol PBX (IP-PBX), which uses the Internet protocol to carry voice calls. The IP-PBX **206** includes an embedded softswitch **210** with cellular protocols corresponding to those of the connected pico-cells **202** (such as GSM, CDMA, and

the like). A softswitch is a software program, which manages and connects calls from one phone to another. Generally, softswitches may provide features including call processing, measuring and monitoring capabilities, call detail reports for the IP endpoints, signaling notifications, flexible call routing and redirection, and the like.

The softswitch **210** in the IP-PBX **206** manages and connects calls to and from phones within the enterprise, including mobile devices **108**. Also, the softswitch **210** may include the full GSM, CDMA, or other cellular feature set provided by the cellular carrier. Because the softswitch **210** is embedded in the IP-PBX **206**, mobile devices **108** registered with the IP-PBX **206** retain their full functionality and host of features offered by or purchased from the cellular carrier on the cellular network **104**. Thus, users can use all the functions of their cell phones or other mobile devices within the enterprise. This full functionality is provided without the need for a dual-mode handset or for enterprise employees to carry multiple devices. The IP-PBX **206** with the embedded soft switch **210** acts as a small standalone cellular switch, with functionality comparable to a standard cellular switch of a cellular network. The enhanced cellular coverage within the enterprise provided by the IP-PBX **206** with the embedded soft switch **210** may allow enterprises to eliminate the use of traditional wire line desk phones, which have limited functionality, and to replace them with readily available, feature-rich cell phones or other mobile devices **108**.

The IP-PBX **206** also comprises a registered visitor database such as a visitor location register (VLR) **212**, a registered home user database such as a home location register (HLR) **214**, and an enterprise customer database **216**. The VLR **212** maintains a list of all mobile devices **108** currently in the coverage area of the IP-PBX **206**, regardless of whether the mobile devices are authorized to access the enterprise pico-cell extension **200**. The HLR **214** maintains a list of subscriber profiles of enterprise wireless users and/or mobile devices **108** that are authorized to access the pico-cell extension **200**. The HLR **214** may also maintain a rule set for determining how and whether to handle calls placed by visitors to the enterprise (i.e., mobile devices not registered with the enterprise IP-PBX **206**). The rule set may, for example, specify whether to carry calls placed by visitors on the pico-cell extension **200**, and if so, whether the visitor will be charged for using the pico-cell extension **200**. The enterprise customer database **216** is a readily modifiable database of customer profiles administered by the enterprise, which is used to periodically populate information into the HLR **214**. The customer database **216** may, for example, define a list of customers (e.g., employees, clients, etc.) and/or mobile devices that are authorized to access the enterprise pico-cell extension **200**, define the features available to end users of the pico-cell extension **200**, rule sets about what information end users can change about their profiles (e.g., PBX features, cellular features, etc.). Typically, the customer database **216** is updated by information technology (IT) staff of the enterprise, or directly by the end mobile users. The customer database **216** may be accessed and updated using any suitable interface, such as a web interface, a direct interface on the mobile device, or the like.

In practice, a cellular carrier still maintains a profile for each subscriber or mobile device **108** in a HLR of the cellular network **104**. When a mobile device **108** enters the enterprise and attempts to access one of the enterprise pico-cells **202**, the VLR **212** registers the mobile device **108** with its IP-PBX **206** as a "roamer." The pico-cell extension **200** (specifically, the BSC **204** or IP-PBX **206**) queries the HLR **214** to confirm that the mobile device **108** is authorized to access the pico-cell

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extension **200** and, if so, the level of services available to the mobile device **108**. The pico-cell extension **200** also conveys to the HLR of the cellular carrier the current location of the mobile device and that the mobile device **108** has entered the coverage area of the specific pico-cell **202**. While the VLR **212**, HLR **214**, and enterprise customer database **216** are shown and described as being part of the IP-PBX **206**, they could instead be implemented as databases stored elsewhere in the pico-cell extension **200** and in communication with the IP-PBX **204** via the extension bus **208**.

In addition to, or instead of, the BSC **204** on the extension bus **208**, the IP-PBX **206** may include a local BSC **218**. The local BSC **218** may be resident in the softswitch **210**, the IP-PBX **206**, or both. By way of example and not limitation, the local BSC **218** may be implemented as a module in the embedded softswitch **210** or as a card or other removable or non-removable memory in the IP-PBX **206**.

The pico-cell extension **200** also includes a router **218** for connection of the pico-cell extension **200** to the cellular network **104** via the Internet **114** and/or a protocol gateway **220** for connection of the pico-cell extension **200** to the cellular network **104** via the PSTN **116**. The media gateway **220** may include media gateway control protocol (MGCP), primary rate interface (PRI), session initiated protocol (SIP), combinations thereof, and the like. Alternatively, one or both of the router **218** and gateway **220** could be integrated with one of the other components of the pico-cell extension **200** (e.g., the BSC **204**, IP-PBX **206**, pico-cell **202**, or the like).

While the various components of the pico-cell extension are shown as being implemented on the enterprise premises, in some implementations, portions of the pico-cell extension could be located offsite, for example, at locations of the cellular carrier. In addition, while the various components of the pico-cell extension are shown as being separate components, these components could be rearranged and/or combined as desired.

In some instances, particularly for smaller enterprises, the enterprise may not have the resources or the desire to administer and update a HLR and/or enterprise customer database. Nevertheless, such enterprises may still want to be able to use their cell phones or other mobile devices within their facilities or other areas of poor cellular coverage. In that case, the enterprise could benefit from the installation of a pico-cell extension requiring minimal administration by the enterprise itself.

FIG. 3 shows another exemplary implementation of a pico-cell extension **300** for a cellular network, in which administration of user and/or mobile device profiles, feature rule sets, and the like is administered by a cellular carrier or other entity external to the enterprise. The pico-cell extension **300** of this implementation is a simplified version of the pico-cell extension **200** of FIG. 2. In this implementation, the pico-cell extension **300** is similar to that shown in FIG. 2, except for the configuration of the IP-PBX **302**. The IP-PBX **302** in this implementation still includes an embedded softswitch **210** with cellular protocols corresponding to those of the connected pico-cells, and a VLR **212** that maintains a list of all mobile devices **108** currently in the coverage area of the IP-PBX **302**. However, the IP-PBX **302** of this implementation does not include a HLR or an enterprise customer database. Instead, functionality of those components is implemented at least partially by a customer provisioning system **304** associated with the cellular carrier or other entity external to the enterprise. The customer provisioning system **304** may perform functions similar to the enterprise customer database described with respect to the implementation of FIG. 2. For example, the customer provisioning system **304** may define a

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list of customers (e.g., employees, clients, etc.) or mobile devices that are authorized to access the enterprise pico-cell extension **300**, the features available to end users of the pico-cell extension **300**, and/or rule sets about what information, if any, end users can change about their profiles (e.g., PBX features, cellular features, etc.). The customer provisioning system **304** may be updated by the cellular carrier at the direction of the enterprise and/or the end users. Alternatively, the end mobile users may be allowed to update at least some of the information on the customer provisioning system directly through, for example, a web interface, an interface on their mobile devices, or the like. Information input to the customer provisioning system **304** subsequently populates the HLR of the cellular network to update the HLR.

In order to benefit from a pico-cell extension **300** according to this implementation, all the enterprise needs to do is purchase and install the pico-cell **202**, IP-PBX **302**, and any other components of the pico-cell extension **300** that they do not already have installed. The pico-cell extension **300** then functions as a part of the larger cellular network, with the cellular carrier controlling who is allowed to access the pico-cell extension **300** in much the same way as they would any other conventional cell site at the direction of the enterprise. Thus, the enterprise can benefit from advantages of a pico-cell extension (e.g., reception within the enterprise facility, reduced costs for phones or mobile devices, reduced wireless service charges, and the like) without being required to administer and update a HLR or enterprise customer database.

FIG. 4 shows the pico-cell **202** of FIGS. 2 and 3 in more detail. As shown, the pico-cell **202** includes a network interface **400** for interfacing the pico-cell **202** with the extension bus **208**, and a protocol converter **402** for converting between cellular protocol and Internet protocol for transmission over the extension bus **208**. The network interface **400** and protocol converter **402** work together to convert protocols associated with mobile devices **108** (e.g., GSM, CDMA, and the like) into protocols suitable for transmission over the extension bus **208**.

The pico-cell **202** also includes an interface **404** between the BSC **204** and base station transceiver subsystems (BTSs) associated with the pico-cell extension **200**. The BSC-BTS interface **404** receives commands from the BSC **204** and converts them into signals understandable by the BTSs. Each BTS generally is comprised of one or more pico-cells. Thus, the pico-cell extension **200** could include one or more BTSs, each comprising one or more pico-cells. As one example, the pico-cell extension **200** might include two BTSs, each BTS corresponding to a building in the enterprise facility. One BTS might include a single pico-cell (e.g., if the BTS corresponds to a small single-room building), while the other BTS might include twenty or more pico-cells (e.g., if the BTS corresponds to an office building). The network interface **400**, protocol converter **402**, and BSC-BTS interface **404** all may be implemented as software or a combination of software and hardware. In the example shown, logic or processor **406** executes the functions of the network interface **400**, protocol converter **402**, and BSC-BTS interface **404** based on interface and conversions stored in memory **408**.

The pico-cell **202** also includes a radio frequency (RF) transceiver **410** for wirelessly transmitting and receiving signals to and from the mobile devices **108** in the coverage area of the pico-cell **202**. The RF transceiver is configured to transmit and receive on applicable cellular channels using cellular protocols, such as GSM, CDMA, and the like. The applicable cellular channels may vary from country-to-country, but in the United States may include, for example, the

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850 megahertz and 1900 megahertz bands. The RF transceiver **410** may include its own onboard memory and/or processor or may use the processor **406** and memory **408** of the pico-cell **202**.

Second Exemplary Pico-Cell Extension

FIG. **5** is a block diagram showing details of another exemplary implementation of a pico-cell extension **500**. The pico-cell extension shown in FIG. **5** is similar in most respects to that shown in FIG. **2**. Accordingly, for the sake of brevity, only those aspects of the pico-cell extension **500** which are different are described below for this implementation.

In the implementation of FIG. **5**, the pico cell extension **500** again includes an IP-PBX **206**, an enterprise customer database **214**, an HLR **216**, a router **218**, and a protocol gateway **220** coupled together by a local area network (LAN) or extension bus **208**. However, in this implementation, the pico-cell extension **500** includes one or more pico-cells **502** using the unlicensed mobile access (UMA) protocol. The pico-cell extension **500** also includes a UMA network controller (UNC) **504**, which is a server connected to the extension bus **208** that acts as a pico-cell aggregator for all the pico-cells **502** within the enterprise. The UNC **502** aggregates the traffic from the pico-cells **502** and communicates with the cellular network **104** to facilitate handover of calls from the pico-cells within the enterprise to cell sites of the cellular network **104** and vice versa.

FIG. **6** shows the pico-cell **502** of FIG. **5** in more detail. As in the implementation of FIG. **4**, the pico-cell **502** includes a network interface **600** for interfacing the pico-cell **502** with the extension bus **208**. In this implementation, however, instead of a protocol converter and BSC-BTS interface, the pico-cell **502** includes a UMA protocol IPSEC tunnel **602**, which provides a secure connection to the UNC **504** and other components on the extension bus **208**. The network interface **600** and UMA protocol IPSEC tunnel **602** interface the pico-cell **502** with the extension bus **208**. The pico-cell **502** also includes an intelligent channel selector **604**, which determines which cellular frequency in the cellular frequency band for the pico-cell **502** to use to downlink signals to mobile devices. The intelligent channel selector **604** may determine what radio frequency (RF) channel to use from among the channels licensed by cellular carrier, depending on the frequencies used by other nearby cell sites, to minimize interference. In this manner, the intelligent channel-selector **604** can continuously or periodically monitor the channels that nearby cell sites are using, query a server on the cellular network to determine what other frequencies are available in the licensed frequency band that are not being used by any of the nearby cell sites, and then select one of the available frequencies to use for the pico-cell **502**.

The network interface **600**, UMA protocol IPSEC tunnel **602**, and intelligent channel selector **604** all may be implemented as software, hardware, or a combination of software and hardware. In the example shown, processor **606** executes the functions of the network interface **600**, UMA protocol IPSEC tunnel **602**, and intelligent channel selector **604** based on interfaces and conversions stored in memory **608**.

The pico-cell **502** also includes a radio frequency (RF) transceiver **610** for wirelessly transmitting and receiving signals to and from the mobile devices **108** in the coverage area of the pico-cell **502**. The RF transceiver is configured to transmit and receive on applicable cellular channels using cellular protocols, such as GSM, CDMA, and the like. As discussed above, the applicable cellular channels may vary from country-to-county, but in the United States may include, for example, the 850 megahertz and 1900 megahertz bands.

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The RF transceiver **510** may include its own onboard memory and/or processor or may use the processor **506** and memory **508** of the pico-cell **502**.

Third Exemplary Pico-Cell Extension

FIG. **7** is a block diagram showing details of another exemplary implementation of a pico-cell extension **700**. The pico-cell extension **700** shown in FIG. **7** is similar in most respects to that shown in FIG. **2**. Accordingly, for the sake of brevity, only those aspects of the pico-cell extension **700** which are different are described below for this implementation.

In the implementation of FIG. **7**, the pico cell extension **700** again includes an IP-PBX **206**, an enterprise customer database **214**, an HLR **216**, a router **218**, and a protocol gateway **220** coupled together by a LAN or extension bus **208**. However, in this implementation, the pico-cell extension **700** includes one or more pico-cells **702** with suitable protocol conversion, such as GSM, CDMA, UMA or the like. The pico-cell extension **700** also includes a UNC **704**, which is a server connected to the extension bus **208** that acts as a pico-cell aggregator for all the pico-cells **702** within the enterprise. The UNC **702** aggregates the traffic from the pico-cells **702** and communicates with the cellular network **104** to facilitate handover of calls from the pico-cells within the enterprise to cell sites of the cellular network **104** and vice versa.

In addition, the implementation of FIG. **7** also includes additional network devices connected to the extension bus **208**, including a LAN switch **706**, a network management server **708**, a domain name server (DNS) **710**, AAA (authentication, authorization, and accounting) protocol **712**, and various other backend services **714**, such as, for example, the ability to allow end user to change his or her wireless profile, business-level policies for service-level agreements, customer relationship management services, transport services (e.g., transmission via the Internet), web policy services, distributed data bases and data storage, identification management services (e.g., meta directories and the like), calendar and administration policies. In some implementations, the softswitch **210** could be embedded in the LAN switch **706**, rather than the IP-PBX **206**, and may include any cellular protocol, such as GSM, CDMA, and the like.

The network management server **708** provides overall management of multiple devices in the customer's network (e.g., workstations, routers, and other network devices). The network management server **708** can schedule communications among devices based on priority of the communications, provide graphical reports (proactively or reactively) in real-time, analysis, polling and/or monitoring of the managed devices, and can send alerts or notifications when problems are detected, or thresholds exceeded. Other network management capabilities may include performance, configuration, accounting, fault, security, and device management.

The DNS **710** stores information associated with domain names and translates the domain names of devices on the LAN or extension bus **208** into corresponding IP addresses. The DNS **710** may also list exchange servers accepting email for each domain.

The AAA protocol **712** authenticates mobile devices **108** that request service on the pico-cell extension **700** by determining whether the mobile device requesting service is a valid user. Authentication may be accomplished, for example, by comparing an identifier of the mobile device (e.g., a phone number, international mobile subscriber identification (IMSI), or the like) to a list of such identifiers in the enterprise customer database **214**. Once a mobile device is authenticated to the system, the AAA protocol **712** then authorizes the mobile device to use some or all of the services of the pico-cell extension **700** based on the end user's subscriber agree-

ment with the cellular provider and/or the user's registration with the enterprise. Once the mobile device is authorized, the AAA protocol **712** accounts for (i.e., tracks) the network resources used by the mobile device **108** for management, planning, billing, or other purposes.

As discussed above, it should be understood that the elements discussed above with regard to the pico-cell extensions may be implemented by software, hardware or a combination thereof. If implemented by software, the software may reside on memory associated with any component of the pico-cell extension, standalone memory provided in communication with the LAN or extension bus, a remote memory storage device, removable/nonremovable memory, a combination of the foregoing, or any other combination of one or more computer-readable media. Any number of programs, program modules, data objects, or other data structures may be stored in memory including an operating system, one or more application programs, other program modules, and program data.

In some implementations, pico-cell extensions may also be configured such that a user may enter commands and information via input devices such as a keyboard, pointing device, serial port, and/or the like. These and other input devices may be connected to the one or more components of the pico-cell extension.

Security functions, such as determining user privilege to enter a cellular carrier's network, or defensive mechanisms against the passing of viruses, may also exist in one or more components of the pico-cell extension, such as the pico-cells, the PBXs, the UNC, the BSC, or another component of the pico-cell extension.

While several exemplary implementations have been described having a pico-cell extension with various different features and components, it should be understood that features and components of the various implementations could be rearranged, omitted, modified, and combined with one another and/or additional features and components. Moreover, while the pico-cell extension is described as being within an enterprise facility, pico-cell extensions may be distributed and at least some of the components may reside remotely from the enterprise facilities. For example, one or more components of the pico-cell extension may be provided by and/or reside with a cellular provider or other telecommunications company.

Exemplary Method of Operation

FIG. **8** is a flow chart showing an exemplary method **800** of providing cellular coverage within a facility. The method **800** may, but need not necessarily, be implemented using a system such as those described herein. In one implementation, the method **800** is implemented on a system having a pico-cell extension including one or more pico-cells coupled to an IP-PBX.

The method includes at **802** receiving at a cellular pico-cell a request from a mobile device using a cellular protocol to access a cellular pico-cell extension. Then, at **804**, the pico-cell transmits the received request from the mobile device to an IP-PBX of the pico-cell extension. At **806**, the pico-cell extension registers the mobile device with a VLR of the IP-PBX of the pico-cell extension. The pico-cell extension also queries a HLR of a remote cellular carrier at **808**, to determine whether the mobile device is authorized to use a remote cellular network. At **810**, the pico-cell extension populates the HLR from a customer database including a list of users authorized to access the pico-cell extension. In practice, the HLR will have been populated prior to being queried at **808**, and may be repopulated continuously as information

in the customer database changes, periodically at set intervals, and/or in response to manual instruction to repopulate the HLR.

If the mobile device is not authorized to access the pico-cell extension, the mobile device is not authenticated and is not allowed to access the pico-cell extension. However, if the mobile device is found based on the customer database to be authorized, at **812**, the pico-cell extension authenticates the mobile device to the cellular pico-cell extension enabling the mobile device to send and receive calls via the pico-cell extension. The method may also include, at **814**, conveying to the HLR of the cellular carrier that the mobile device is in the coverage area of the pico-cell.

Once the mobile device has been authorized to the pico-cell extension, it will be allowed to transmit and receive calls using the pico-cells of the pico-cell extension. Thus, at **816**, the pico-cell extension connects a call between the mobile device and another line using an embedded cellular soft-switch of the IP-PBX, which is in communication with the pico-cell. If the mobile device moves outside the coverage area of the pico-cell, then at **816**, the pico-cell extension hands over the call from the pico-cell to another pico-cell associated with the pico-cell extension. In this manner, the mobile device functions properly as it is moved around the facility. A similar handover may be performed between a pico-cell of the pico-cell extension and an external cell site of the cellular network.

It should be understood that certain acts in method **800** need not be performed in the order described, may be modified and/or may be omitted entirely, depending on the circumstances and the needs of the enterprise. For example, the pico-cell extension need not necessarily query a customer database as in step **810** and might instead allow any mobile device in the facility to access the pico-cell extension.

Also, any of the acts described above may be implemented by a processor or other computing device based on instructions stored on one or more computer-readable media associated with the pico-cell extension.

CONCLUSION

Although the invention has been described in language specific to structural features and/or methodological acts, it is to be understood that the invention is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as exemplary forms of implementing the invention.

What is claimed is:

1. A system comprising:

- a pico-cell located within a building for carrying one or more calls placed to and from at least one mobile device in the building, the pico-cell having a wireless protocol for carrying at least the one or more calls placed to and from the at least one mobile device in the building using the wireless protocol; and
- a call distributor in communication with the pico-cell for handling the calls carried by the pico-cell, the call distributor comprising:
 - an embedded wireless switch for routing the calls placed to and from the mobile devices in the building using the wireless protocol; and
 - a registered home user database in communication with the pico-cell for storing a list of user devices authorized to access the pico-cell and place the calls carried by the pico-cell.

2. The system of claim 1, wherein the system is in communication with at least one of the public switched telephone

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network (PSTN) and the Internet for transmission and reception of at least one call to and from locations outside the building.

3. The system of claim 1, wherein the registered home user database is disposed in the building or is disposed outside the building and is administered by a wireless carrier, the registered home user database comprises a home location register (HLR).

4. The system of claim 1, the call distributor further comprising a registered visitor database for storing information associated with at least one mobile device in the coverage area of the call distributor, wherein the registered visitor database comprises a visitor location register (VLR).

5. The system of claim 1, further comprising at least one additional pico-cell at another location within the building, the call distributor being in communication with each pico-cell in the building for handling calls carried by the pico-cells.

6. The system of claim 1, wherein the call distributor comprises an Internet protocol private branch exchange (IP-PBX), and the embedded wireless switch comprises a cellular softswitch.

7. The system of claim 6, further comprising a media gateway for converting session initiated protocol (SIP) signals from the IP-PBX to circuit time-division multiplexed (TDM) signals for communication with the public switched telephone network (PSTN).

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8. The system of claim 1, further comprising a base station controller (BSC) for controlling handovers between the pico-cell and another pico-cell or cell site.

9. The system of claim 1, further comprising a customer database in communication with the pico-cell for storing at least one of a list of users authorized to use the pico-cell or a list of mobile devices authorized to be used with the pico-cell.

10. The system of claim 1, wherein the pico-cell comprises a network interface for interfacing the pico-cell with the call distributor, and for converting protocols associated with the mobile devices into protocols suitable for transmission to the call distributor.

11. The system of claim 1, wherein the pico-cell comprises a radio frequency (RF) transceiver for transmitting and receiving signals on cellular channels and using cellular protocols, and a protocol converter for converting between cellular protocol and Internet protocol.

12. The system of claim 1, wherein the pico-cell comprises a radio frequency (RF) transceiver for transmitting and receiving signals on cellular channels and using cellular protocols, an unlicensed mobile access (UMA) protocol Internet protocol tunnel, and an intelligent channel selector.

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