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(54) METHOD AND SYSTEM FOR ENABLING SEAMLESS ROAMING IN A WIRELESS NETWORK

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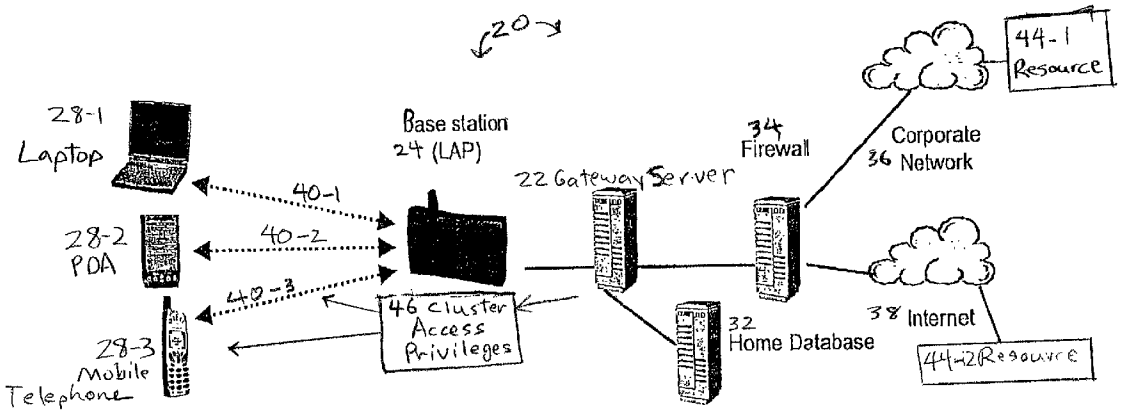
(57) **ABSTRACT**

A gateway server manages connections in a wireless local area network (WLAN). The gateway server provides context information, such as an IP address, that is stored after being previously allocated to a mobile device in a previous connection to the WLAN. The gateway server reassigns the IP address to the mobile device after it reconnects to the WLAN after a disconnection, thus providing seamless roaming for the mobile device from WLAN to WLAN (or subnets within one WLAN) without requiring the user of the device to re-register. The gateway server also provides cluster information (e.g., as part of the context information) for a mobile device making a new connection to the WLAN, such as access privileges associated with the cluster of users of the mobile devices. The gateway server also provides load balancing among two or more WLAN's by directing a newly connection mobile device to another WLAN (or subnet), if less congestion results.



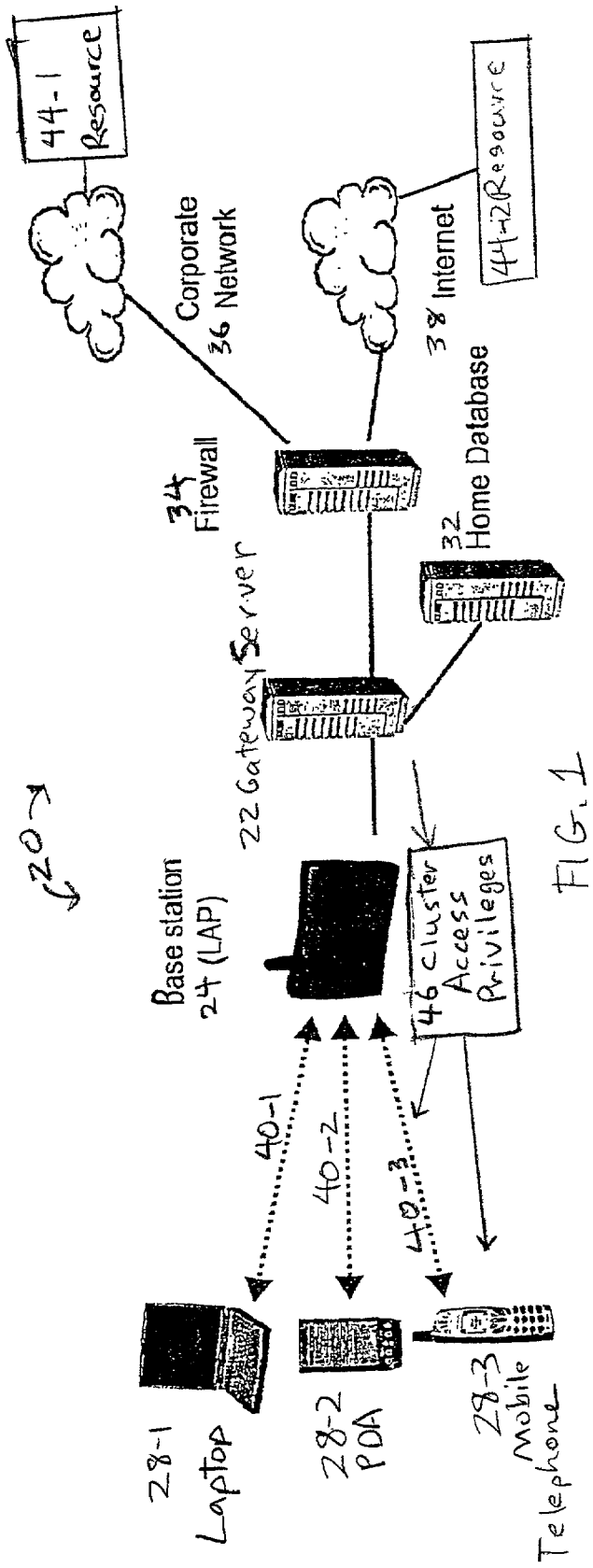

20
44-1 Resource
Corporate 36 Network
38 Internet
44-2 Resource
34 Firewall
32 Home Database
22 Gateway Server
Base station 24 (LAP)
46 Cluster Access Privileges
40-1
40-2
40-3
28-1 Laptop
28-2 PDA
28-3 Mobile Telephone

FIG. 1

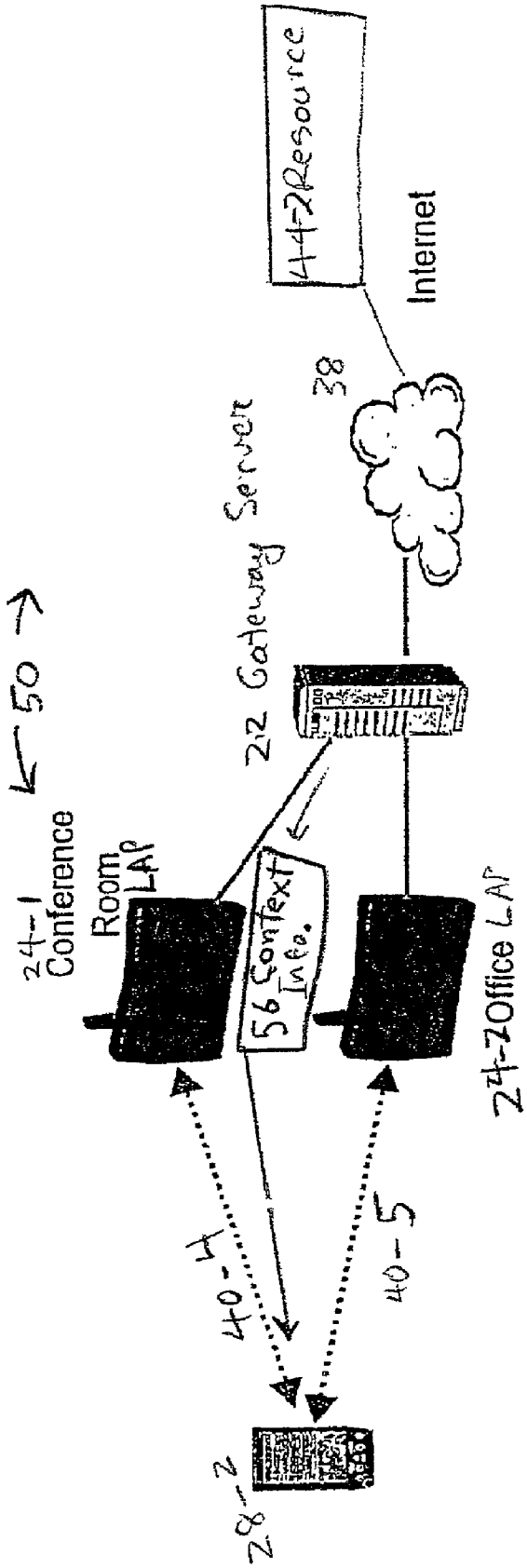

50
24-1 Conference Room LAP
22 Gateway Server
38
44-2 Resource
Internet
56 Context Info.
24-2 Office LAP
40-4
40-5
28-2

FIG. 2

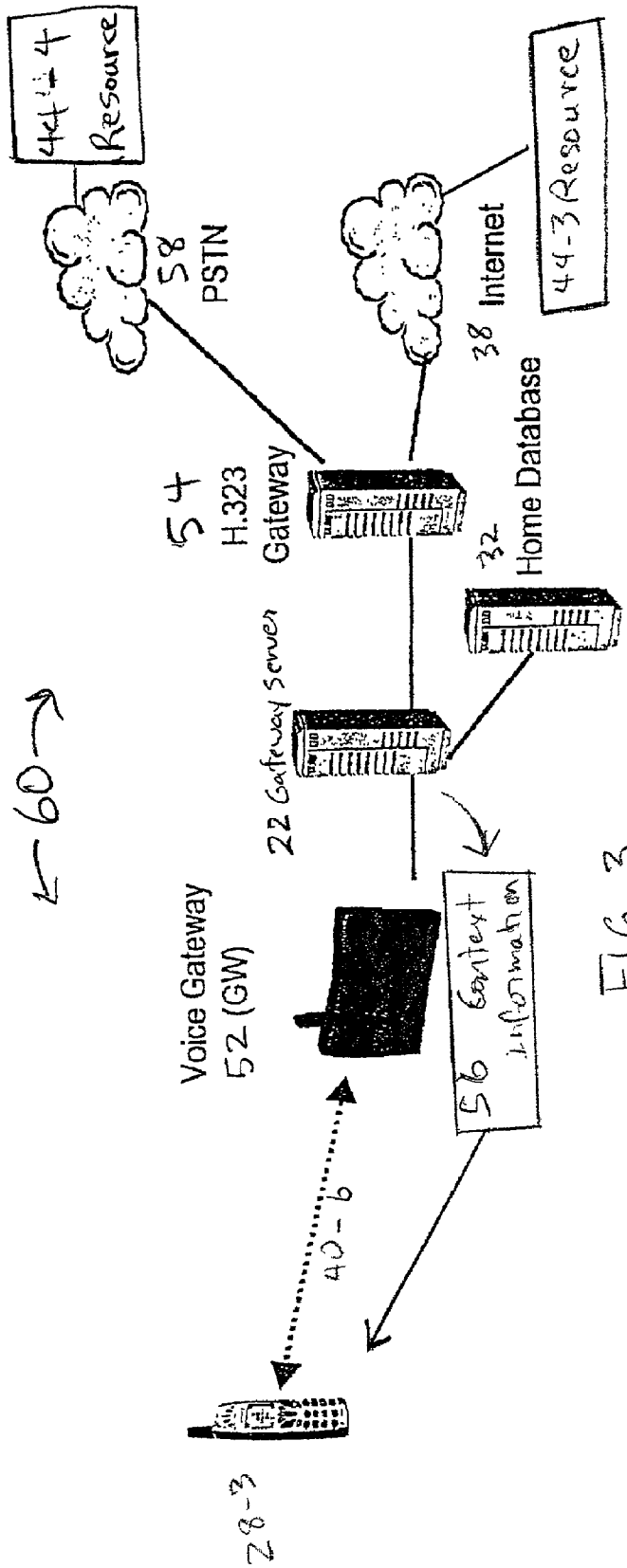

44-4 Resource
58 PSTN
38 Internet
44-3 Resource
54 H.323 Gateway
32 Home Database
22 Gateway Server
60
Voice Gateway 52 (GW)
56 Context information
40-6
28-3

FIG. 3

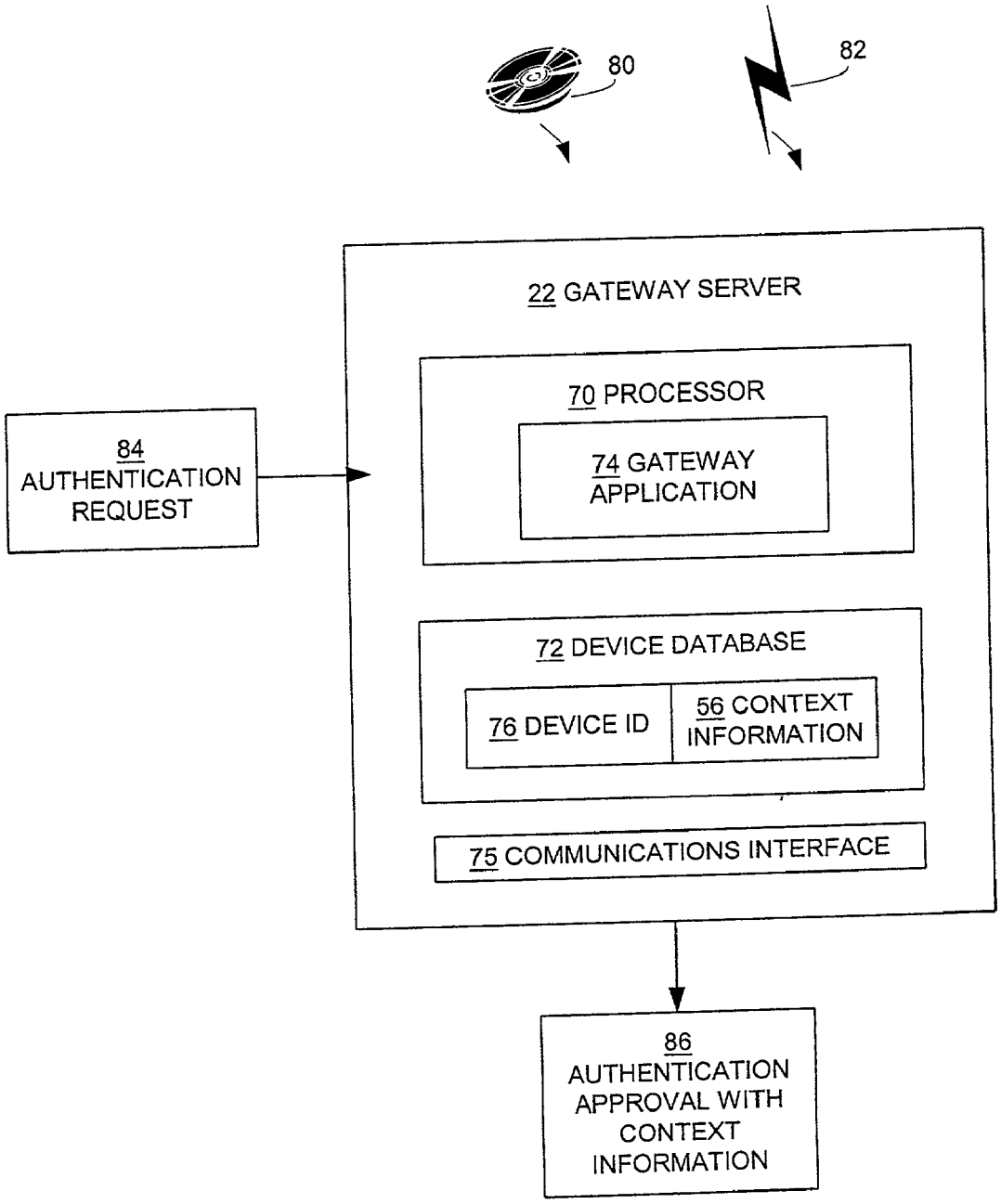

80
82
22 GATEWAY SERVER
70 PROCESSOR
74 GATEWAY APPLICATION
84 AUTHENTICATION REQUEST
72 DEVICE DATABASE
76 DEVICE ID
56 CONTEXT INFORMATION
75 COMMUNICATIONS INTERFACE
86 AUTHENTICATION APPROVAL WITH CONTEXT INFORMATION

FIG. 4

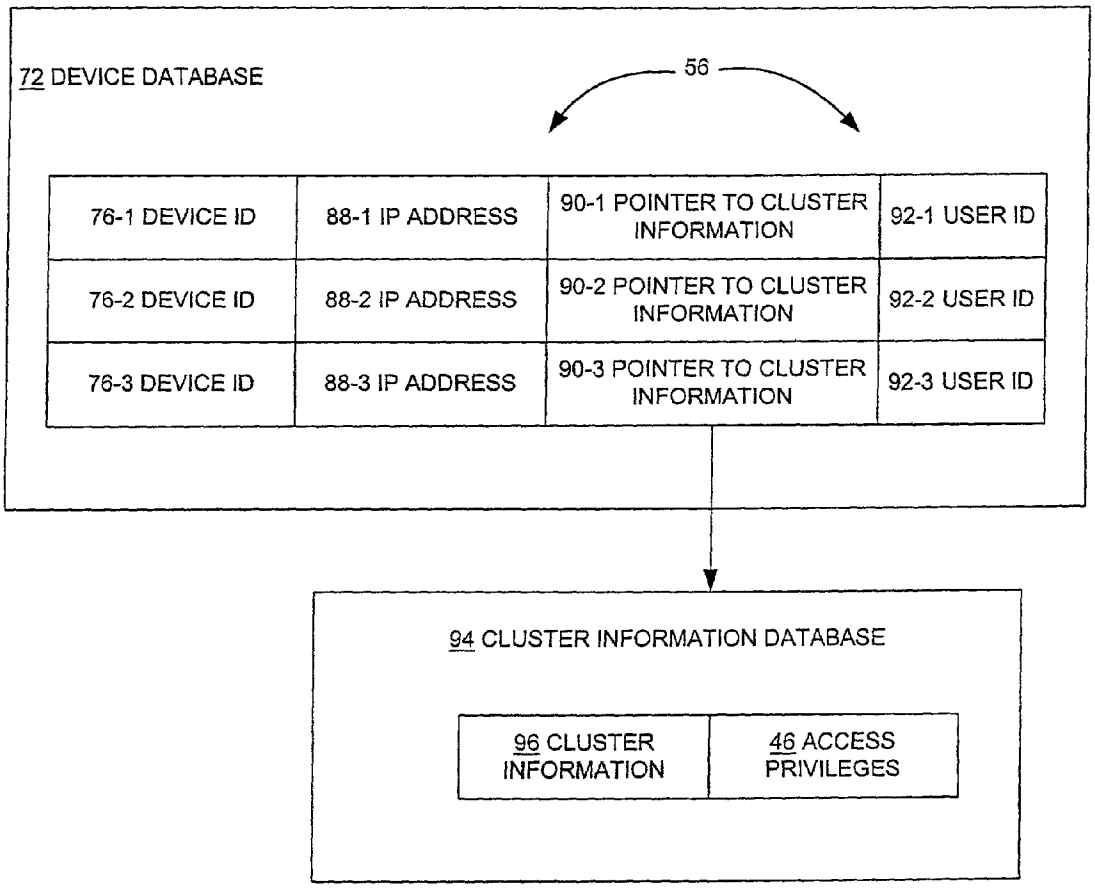

72 DEVICE DATABASE
56
76-1 DEVICE ID
88-1 IP ADDRESS
90-1 POINTER TO CLUSTER INFORMATION
92-1 USER ID
76-2 DEVICE ID
88-2 IP ADDRESS
90-2 POINTER TO CLUSTER INFORMATION
92-2 USER ID
76-3 DEVICE ID
88-3 IP ADDRESS
90-3 POINTER TO CLUSTER INFORMATION
92-3 USER ID
94 CLUSTER INFORMATION DATABASE
96 CLUSTER INFORMATION
46 ACCESS PRIVILEGES

FIG. 5

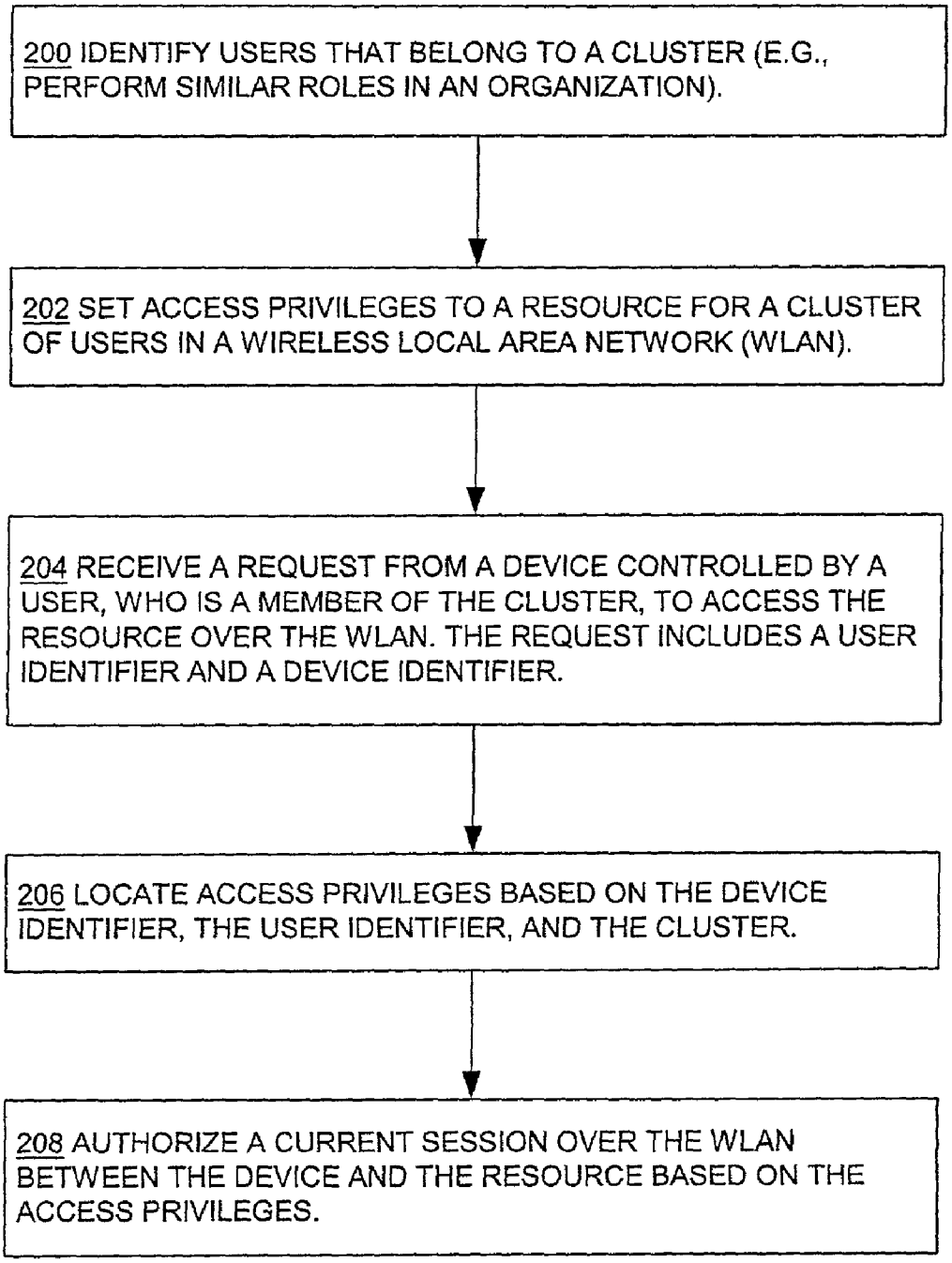

200 IDENTIFY USERS THAT BELONG TO A CLUSTER (E.G., PERFORM SIMILAR ROLES IN AN ORGANIZATION).
202 SET ACCESS PRIVILEGES TO A RESOURCE FOR A CLUSTER OF USERS IN A WIRELESS LOCAL AREA NETWORK (WLAN).
204 RECEIVE A REQUEST FROM A DEVICE CONTROLLED BY A USER, WHO IS A MEMBER OF THE CLUSTER, TO ACCESS THE RESOURCE OVER THE WLAN. THE REQUEST INCLUDES A USER IDENTIFIER AND A DEVICE IDENTIFIER.
206 LOCATE ACCESS PRIVILEGES BASED ON THE DEVICE IDENTIFIER, THE USER IDENTIFIER, AND THE CLUSTER.
208 AUTHORIZE A CURRENT SESSION OVER THE WLAN BETWEEN THE DEVICE AND THE RESOURCE BASED ON THE ACCESS PRIVILEGES.

FIG. 6

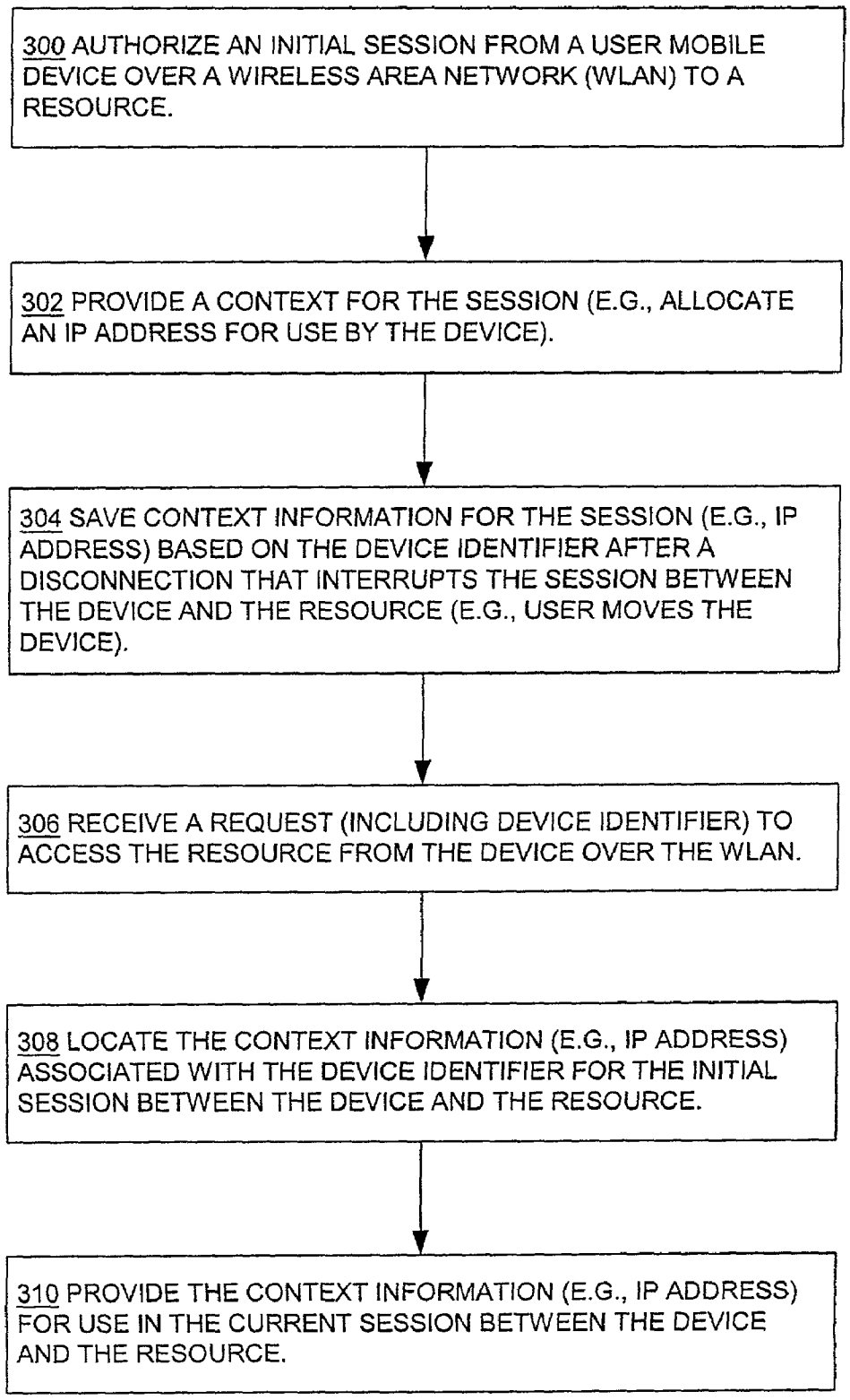

300 AUTHORIZE AN INITIAL SESSION FROM A USER MOBILE DEVICE OVER A WIRELESS AREA NETWORK (WLAN) TO A RESOURCE.
302 PROVIDE A CONTEXT FOR THE SESSION (E.G., ALLOCATE AN IP ADDRESS FOR USE BY THE DEVICE).
304 SAVE CONTEXT INFORMATION FOR THE SESSION (E.G., IP ADDRESS) BASED ON THE DEVICE IDENTIFIER AFTER A DISCONNECTION THAT INTERRUPTS THE SESSION BETWEEN THE DEVICE AND THE RESOURCE (E.G., USER MOVES THE DEVICE).
306 RECEIVE A REQUEST (INCLUDING DEVICE IDENTIFIER) TO ACCESS THE RESOURCE FROM THE DEVICE OVER THE WLAN.
308 LOCATE THE CONTEXT INFORMATION (E.G., IP ADDRESS) ASSOCIATED WITH THE DEVICE IDENTIFIER FOR THE INITIAL SESSION BETWEEN THE DEVICE AND THE RESOURCE.
310 PROVIDE THE CONTEXT INFORMATION (E.G., IP ADDRESS) FOR USE IN THE CURRENT SESSION BETWEEN THE DEVICE AND THE RESOURCE.

FIG. 7

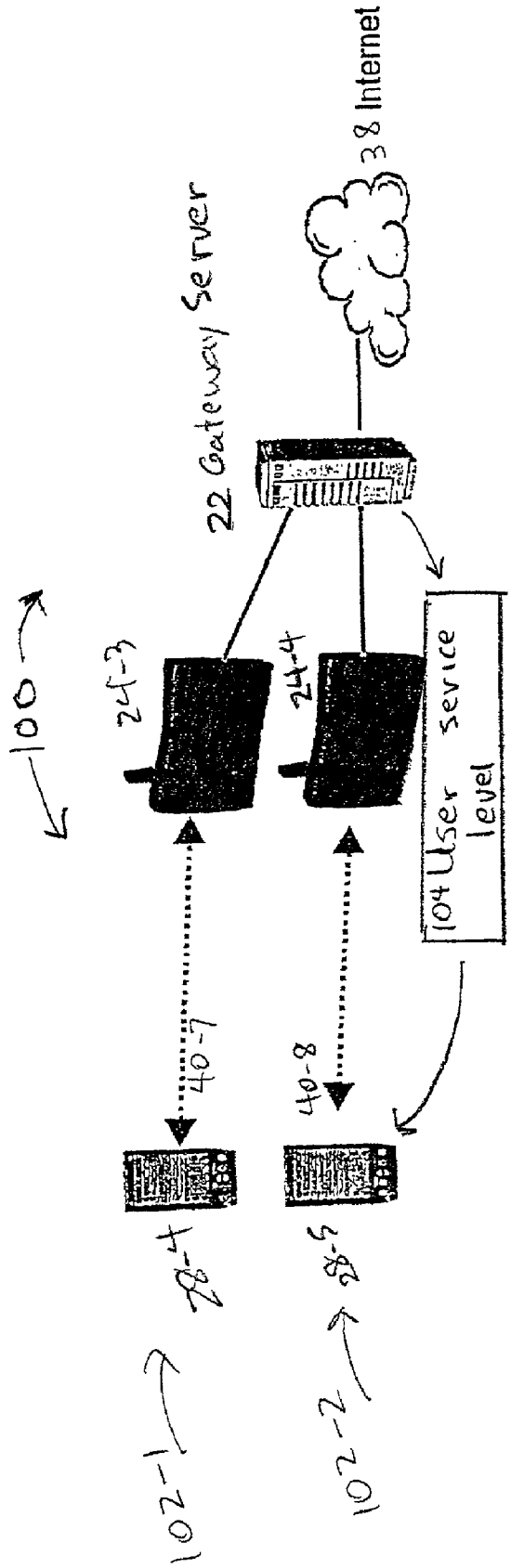

100
24-3
24-4
22 Gateway Server
38 Internet
104 User Service level
40-7
40-8
28-4
28-5
102-1
102-2

FIG. 8

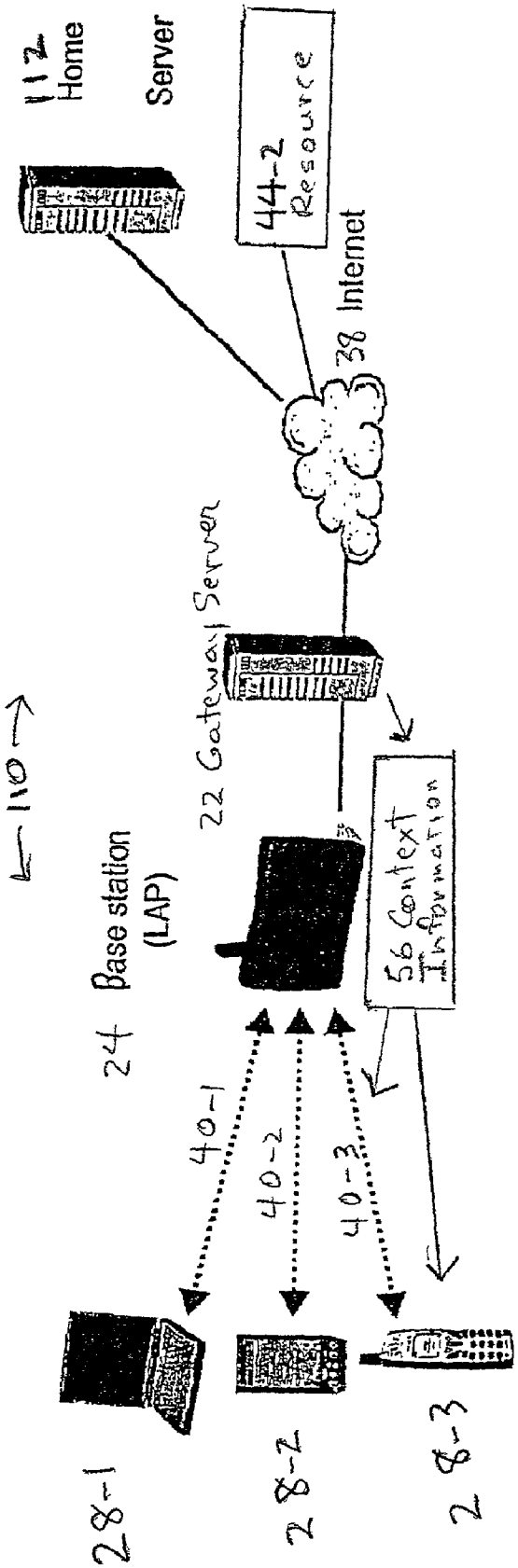

112 Home Server
44-2 Resource
38 Internet
22 Gateway Server
110
24 Base station (LAP)
56 Context Information
40-1
40-2
40-3
28-1
28-2
28-3

FIG. 9

METHOD AND SYSTEM FOR ENABLING SEAMLESS ROAMING IN A WIRELESS NETWORK

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional application Ser. No. 60/220,385 filed on Jul. 24, 2000, the entire teachings of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Networked desktop computing is typical in both the office and home. Networking of mobile devices, such as mobile telephones, laptop computers, headsets, and PDA's (Personal Digital Assistants), is more difficult. One problem has been that there has not been a commonly accepted standard approach for attaching such devices, such as the mobile equivalent of a LAN (Local Area Network) card or a modem, to a WLAN (wireless LAN).

[0003] Bluetooth (BT) is a low cost wireless connection technology. The Bluetooth technology is described in the Bluetooth specification version 1.1, available from Bluetooth SIG, Inc. (see also the *www.bluetooth.com* web site.) This technology provides for a common attachment approach for different devices, and so enables mobile phones, laptops, headsets, and PDA's to be easily networked in the office and eventually in public locations. Other standards such as the IEEE 802.11 (Institute of Electrical & Electronics Engineers) and ETSI (European Telecommunications Standards Institute) HIPERLAN/2 provide a generally similar connection function as Bluetooth and may be used to support WLAN (see the IEEE 802.11 "Wireless LAN Medium Access Control (MAC) and Physical Layer Specifications" and ETSI specifications for HIPERLAN/2 such as ETSI document number TR 101 683, "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; System Overview").

[0004] Wireless LAN (WLAN) access points (LAP's) such as those used by 802.11 and Bluetooth are part of an IP subnet; that is, a range of IP addresses that are normally used by all the devices connected to a section of the network delineated by a router (which may also be known as a gateway), direct packets to and from devices that are outside the subnet.

[0005] In one conventional approach, devices (e.g., a router, gateway, or mobile devices) inside the subnet are primarily identified by their MAC address. This is a fixed address tied to the Ethernet card. IP addresses are associated with MAC addresses. There can be multiple IP addresses associated with a single MAC address. Each router or gateway device on the subnet maintains a cache which maps IP addresses within the sub-net to the associated MAC addresses. Data packets are sent to the MAC address associated with the IP address by the cache. (For destinations outside the sub-net the data is sent to the router which then forwards them.)

[0006] In order for a device (e.g., router or gateway) to find the MAC address associated with a particular IP address, an ARP (address resolution protocol) is used. The device (e.g., router or gateway) follows the ARP and sends out a broadcast message asking for the device associated with the included IP address to respond with its MAC address. Once received it is added to the cache.

[0007] For a situation where there are mobile devices attached to an access point then the mobiles MAC address is associated with an IP address from within the subnet IP address space. If the mobile device moves to another access point that is in the same subnet then all that is required is for the new access point to realize that it must respond to the MAC address of the mobile device that has just associated itself, and the previous access point to cease to response to that MAC address. The MAC to IP address cache does not need to be changed.

[0008] If, however, the mobile device moves to an access point connected to another subnet then the local MAC to IP cache does not apply. The mobile device would typically be required to obtain a new IP address and so break the previous connection. The user of the mobile device is typically re-required to re-establish a stateful end to end connection such as IPSec (IP Security Protocol, an encryption protocol from the Internet Engineering Task Force (IETF), an organized activity of the Internet Society), and so the user may be required to re-register with the WLAN. For example, the user may be required to re-enter a PIN (personal identification number) when connecting to a new subnet.

SUMMARY OF THE INVENTION

[0009] To be truly effective, mobile users must be able to move their mobile devices freely from location to location. For example, users must be able to move their mobile devices from the office to their own conference room to the airport lounge to their client's conference room, while maintaining access to the same set of resources without manually registering anew in each location. They should also be able to send and receive messages and voice calls, wherever they are located. Connection servers, such as routers, WLAN gateways, and security servers, should be able to handle a mobile device that moves its connection to the network from access point to access point, and from public to private networks.

[0010] Mobile devices also need to be allocated the appropriate amount of bandwidth to their class of service, and able to find and access the resources they need.

[0011] In the case of a BT based network or other wireless local area networks (WLAN), there are likely to be many small coverage areas and many network operators, and users are likely to roam much more frequently from one small coverage area to another. So there is a need for an automatic registration system that registers users as they move from one WLAN coverage area serviced by one wireless base station LAP (LAN access point) to another coverage area serviced by another wireless base station LAP, as well as between coverage areas supported by different security servers and network operators. The solution must be cost effective, but also scalable enough for it to be extendable to many thousands of service providers and millions of users. It is also important to implement the solution only in the network side, to avoid changes to the mobile device such as adding new software or hardware.

[0012] In general, the techniques of the invention manage WLAN connectors and maintain context information for connections to enable a user to move a mobile device so that

its connection to the network moves from access point to access point, and from public to private networks without requiring re-registration by the user ("seamless roaming"). The solution provided by the invention described herein is an approach that is used by the network operator to enable roaming from subnet to subnet inside that WLAN supported by the network operator. This approach of the invention provided herein describes how to integrate separate WLAN coverage areas so that users of mobile wireless devices may seamlessly roam from location to location. In particular, it describes how to enable users with Bluetooth devices (or other wireless technologies) to move from wireless access node to another coverage area without requiring the user to re-register. It goes on to describe how independent networks can be linked so as to enable users to move easily between coverage areas managed by different servers and different operators.

[0013] With an existing conventional WLAN installation where there are multiple overlapping WLAN's, it is up to the mobile device to decide which WLAN to join, and the mobile device makes this decision irrespective of the loading level of the WLAN or its service level. This conventional approach can lead to a problem of having all the mobiles connected to the nearest access point and none attached to an access point that is farther away. The approach of the invention allows directing mobile devices away from busy or highly loaded WLAN's to a WLAN connection that provides better service for the mobile device and less overall congestion.

[0014] Thus, the present invention provides a method and system for managing access by a user to a resource over a WLAN by a gateway server. In particular, the method of the system (e.g., gateway server) includes setting access privileges to the resource for a cluster of users of the WLAN and receiving a request from a device controlled by the user to access the resource over the WLAN. The user has a membership in the cluster, and the request includes a user identifier for the user and a device identifier for the device making the request. The membership in a cluster typically reflects the user's role in an organization, such as a student who takes history classes at a university and is thus a member of the history cluster and is allowed access to a database of historical information. In another example, an accountant in a company is a member of a financial cluster and is allowed access to financial records. The method further includes locating access privileges based on the device identifier, the user identifier, and the cluster and authorizing a current session between the device and the resource based on the access privileges. Thus a gateway server can determine the access privileges for a mobile device seeking access to a WLAN based on the cluster the user belongs to.

[0015] In another aspect, the present invention provides a method and system (e.g., gateway server) for managing context information for a wireless local area network. The method includes receiving a request to access the resource over the WLAN, in which the request includes a device identifier for a device making the request and locates context information associated with the device identifier. The context information is associated with a previous session between the device and the resource. The method further includes providing the context information for use in a current session between the device and the resource. Thus the gateway server can reassign context information (e.g., IP address) from a previous session or connection to the mobile device, based on the device identifier without requiring re-registration by the user of the mobile device.

[0016] In a further aspect, the present invention provides a method and system (e.g., gateway server) for balancing the load among wireless local area networks. The method includes receiving an indication that a device has established a first connection with a first wireless local area network, the device having a device identifier and determining a user service level associated with the device based on the device identifier and based on a load level for the first wireless local area network in comparison to the load levels associated with each of the other wireless local area networks available for connection by the device. The method further includes directing the device to establish a second connection with a second wireless local area network based on the user service level and the load level of the first wireless local area network, if the second connection provides a preferable balancing of loads among the wireless local area networks. Thus, if the first WLAN that the mobile device connects to is congested, the gateway server can direct the mobile device to another WLAN that should provide a better level of service for the mobile device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0018] **FIG. 1** illustrates a networked system that enables sharing of cluster access privileges in a WLAN provided by a gateway server configured according to the invention.

[0019] **FIG. 2** illustrates a networked system that enables roaming of a wireless device between locations supported by a gateway server configured according to the invention.

[0020] **FIG. 3** illustrates a voice enabled networked system that enables sharing of context information provided by a gateway server configured according to the invention.

[0021] **FIG. 4** illustrates an example of a gateway server suitable for use in the networked systems of **FIG. 1, 2**, and **3**.

[0022] **FIG. 5** illustrates an example of a device database suitable for use with the gateway server of **FIG. 4**.

[0023] **FIG. 6** illustrates a procedure for authorizing access based on cluster access privileges.

[0024] **FIG. 7** illustrates a procedure for managing context information in a WLAN.

[0025] **FIG. 8** illustrates a networked system in a WLAN environment with multiple subnets or channels.

[0026] **FIG. 9** illustrates a networked system in a WLAN environment with a gateway server and a home server.

DETAILED DESCRIPTION OF THE INVENTION

[0027] A description of preferred embodiments of the invention follows.

[0028] **FIG. 1** illustrates a networked system **20** that enables sharing of cluster access privileges **46** in a WLAN provided by a gateway server **22** configured according to the invention. The networked system **20** includes one or more base stations or LAP's (LAN access points) **24** that provide access to a WLAN, mobile devices **28** (e.g., **28-1**, **28-2**, and **28-3**), home database **32**, firewall **34**, corporate network **36**, Internet **38**, and various resources **44**. In general, the invention may be used with any suitable wireless LAN, such as a WLAN based on Bluetooth, IEEE 802.11, ETSI HIPERLAN/2 or similar protocols. The mobile devices **28** are any suitable portable communications device that supports the Bluetooth (or other suitable WLAN protocol such as IEEE 802.11 or ETSI HIPERLAN/2) communications protocol. In a preferred embodiment, the mobile device **28** uses a radio communication frequency greater than 2000 megahertz (e.g., frequencies suitable for Bluetooth, IEEE 802.11, or ETSI HIPERLAN/2). The mobile devices **28** include, for example, a laptop computer **28-1**, a PDA (personal digital assistant) **28-2**, and a mobile telephone **28-3**. The connections **40** (e.g., **40-1**, **40-2**, and **40-3**) are Bluetooth wireless connections established between each mobile device **28-1**, **28-2**, and **28-3** and the LAP base station **24**. The cluster access privileges **46** are access privileges providing access to a resource **44** (e.g., **44-1** or **44-2**) from a mobile device **28** over a connection **40** and through the networked system **20**. The resource **44-1** may be a server computer, database, or other electronic or computing resource available through the corporate network **36**. The resource **44-2** may be a server computer, database, or other electronic or computing resource available through a global network, such as the Internet **38**. A resource **44** is not required to be a computer system, but may be a component of a computer system, such as a database or application available on a server computer. The cluster access privileges **46** provide access to a resource **44** or specify the nature of the access, that is, the amount of bandwidth made available to a device **28** by the base station LAP **24** for a user that is a member of the respective cluster, as will be discussed in more detail later. The firewall **34** is a server or other computing device that controls access to the corporate network **36**. The home database **32** is a centralized or home database (or computer server with database) that stores security certificates, such as those used to authenticate a user of a mobile device **28**.

[0029] In a general summary of the operation of the networked system **20**, the Bluetooth base station **24** uses a Bluetooth inquiry mode to discover devices **28** within radio communication range (based on frequencies supported by the Bluetooth protocol) of the base station **24**, and/or a device **28** uses the inquiry mode to discover if the device **28** is within radio communication range of one or more base station LAN access points **24** (LAP's) that have advertised their presence within range of the device **28**. The mobile device **28** then requests the establishment of a connection **40** to an appropriate LAP **24**. A link is established using point to point connections (PPP) **40** over RFCOMM (a serial emulation protocol based on ETSI TS 07.10) and L2CAP (logical link controller adaptation protocol) according to techniques typical for Bluetooth WLAN. For other WLAN protocols such as 802.11b the link is made at protocol level **2** as opposed to protocol level **3** (PPP), so the link establishment is made using the TCP/IP protocol.

[0030] For devices **28** requesting Internet only access, then Bluetooth PIN (personal identification number) authentication can be used. The gateway server **22** allocates to the device **28** an IP address that the corporate firewall **34** blocks so as to deny access to the corporate network **36** by the device **28**. In one embodiment, the gateway server **22** is a RADIUS (remote authentication dial-in service) server that is typically used to authenticate dial-in access to corporate networks **36** and Internet Service Provides (ISP's) and also provide Bluetooth gateway functionality and SDP (service discovery protocol) functionality.

[0031] For devices **28** requiring corporate LAN access, then strong authentication is used based on EAP (Extensible Authentication Protocol) based on a strong system based on SPEKE (Simple Password Authenticated Exponential Key Exchange), Smartcards, or Security Dynamics (e.g., Secure ID token card).

[0032] In a preferred embodiment, the gateway server **22** database is extended to map Bluetooth device numbers to "personal clusters" and hence to a person. Logging on one device **28** in a personal cluster can automatically enable all other devices **28** on the same LAP **24** to log on (that are in the same personal cluster) as determined by the users of the devices **28**, as will be described in more detail later.

[0033] As described above, **FIG. 1** illustrates one networked system **20** suitable for use with the gateway server **22** of the invention. **FIG. 2** illustrates another networked system **50** suitable for use with the gateway server **22**. **FIG. 3** illustrates a voice enabled networked system **60** suitable for use with the gateway server **22**. **FIG. 4** illustrates the gateway server **22** shown in **FIGS. 1, 2**, and **3** in more detail.

[0034] **FIG. 2** illustrates the networked system **50**, which enables roaming of a wireless mobile device **28** (e.g., shown in **FIG. 2** as PDA mobile device **28-2**) between locations supported by the same gateway server **22**. In addition to what is illustrated in **FIG. 1**, **FIG. 2** illustrates a conference room base station LAP **24-1**, an office base station LAP **24-2**, and context information **56** provided from the gateway server **22** to the mobile device **28-2**. In a preferred embodiment, the conference room LAP **24-1** is a Bluetooth base station that provides WLAN connections (e.g., connection **40-4**) for a conference room (e.g., a conference room in a corporate office or other organizational setting). In a preferred embodiment, the office LAP **24-2** is a Bluetooth base station that provides WLAN connections **40** (e.g., connection **40-5**) for one or more offices in a corporate or other organizational setting. The context information **56** is information (e.g., an IP address) associated with a particular mobile device **28-2**, such as information indicating the context of an earlier or initial session of the mobile device **28-2** retained (or pointed to) by the gateway server **22**, as will be discussed in more detail later.

[0035] In reference to **FIG. 2**, roaming occurs as a user moves a mobile device **28-2** from one location to another, for example, from the conference room into an office. For example, first the device **28-2** is authenticated and connected via a PPP connection **40-4** to conference room LAP **24-1**. The user moves out of range and so the packet error rate on the connection **40-4** increases rapidly. The PPP controller in the conference room LAP **24-1** clears down the connection **40-4**. The user then moves the device **28-2** into range of the office LAP **24-2** and uses inquiry mode to discover the LAP **24-2**. The device **28-2** connects to the LAP **24-2** and re-authenticates. The gateway server **22** recognizes the

unique device identifier and re-assigns the IP address and configuration from the previous connection **40-4** to the device **28-2** to be used with the new connection **40-5**. It also upgrades the user location.

[**0036**] This approach described immediately above will take at least 10 seconds. For more rapid hand-over it is necessary for the conference room LAP **24-1** to signal to the gateway server **22** that it is terminating the connection **40-4**, and then for the gateway server **22** to instruct all the local LAP's **24** to page the device **28-2** by name.

[**0037**] **FIG. 3** illustrates a networked system **60** that enables communication of a voice enabled device **28** (e.g., shown in **FIG. 3** as mobile telephone **28-3**) over a WLAN. In addition to what is shown in **FIG. 1**, **FIG. 3** illustrates a Bluetooth voice gateway **52**, an H.323 gateway **54**, a PSTN **58** (public switched telephone network), a voice enabled Internet resource **44-3**, and a PSTN resource **44-4**. The Bluetooth voice gateway **52** is adapted to handle voice communications, such as from the mobile telephone **28-3**. The voice gateway **52** is one example of a base station LAP **24**. The voice gateway **52** is one example of a Bluetooth base station LAP **24**. The H.323 gateway **54** is a server that handles voice-based communications between the gateway server **22** and a PSTN **58** or the Internet **38** (based on the ITU-T H.323 standard for video and/or audio transmission over packet switched networks). The gateway server **22** provides context information **56**, such as an IP address, that was previously allocated to the mobile telephone in a previous connection (in a manner similar to the use of context information **56** as described for **FIG. 2**).

[**0038**] In a general summary of the operation of the networked system **60**, the voice enabled mobile device **28** registers with a voice gateway LAP **52** connected to a gateway server **22** when in range. The voice gateway LAP **52** authenticates with gateway server **22** and informs an H.**323** gateway **54** (connected to a PSTN **58**, the Internet **38**, or voice-enabled network) of the new user. The H.**323** gateway **54** maps the device **28** to a phone number so that the user may receive calls that are made to the user's home H.323 from the PSTN **58** or the Internet **38**. Typically, the voice gateway LAP **52** is a separate device from a data only LAP **24** so that voice and data would not normally be on the same subnet (e.g., Bluetooth scatternet).

[**0039**] If the user roams away from voice gateway LAP **52**, then a telephone call for the user is received by a centralized home H.323 server which then forwards the call to the relevant H.323 gateway **54** by looking up the current user location in the gateway server **22** (or a centralized security database or server that maintains information or user locations as indicated by local gateway servers **22** or local security servers).

[**0040**] **FIG. 4** illustrates an example of a gateway server **22** suitable for use in the networked systems of **FIG. 1**, **2**, and **3**. The gateway server **22** includes a digital processor **70** (e.g., microprocessor), a device database **72** (e.g., stored in a memory or on a hard disk drive) and a communications interface **75**. The digital processor **70** hosts and executes a preferred embodiment of a gateway application **74** that manages context information **56** (e.g., IP address **88** allocated to the mobile device **28**) for the mobile device **28** and generally manages the connection between the mobile device **28** and the resource **44** (e.g., routes packets between the mobile device **28** and the resource **44**) In general, when the gateway server **22** is referred to herein as performing some function, this means that the digital processor **70** of the gateway server **22** is performing that function based on the instructions of the gateway application **74** that is hosted and executing on the digital processor **70**. The device database **72** stores device identifiers **76** for mobile devices **28** and, in a preferred embodiment, context information **56** for each device identifier **76**. The communications interface **75** includes communications hardware and software that provides communications over network or other connections (wireless or cable) to other entities such as the base station LAP **24** or a server over the Internet. An authentication request **84** is a Bluetooth (or other WLAN) request originating from a mobile device **28** to authenticate the device **28** and establish a connection **40** between the device **28** and a base station LAP **24**. The authentication approval with context information **56** is an approval of the authentication request **84** that includes the context information **56** (e.g., IP address previously assigned to the device identifier **76** in an earlier session of the device **24** previously authenticated by the gateway server **22**). The cluster access privileges **46** illustrated in **FIG. 1** is one example of context information **56**.

[**0041**] In one embodiment, a computer program product **80**, including a computer readable or usable medium (e.g., one or more CDROM's, diskettes, tapes, etc.), provides software instructions for the gateway application **74** (see **FIG. 4**). The computer program product **80** may be installed by any suitable software installation procedure, as is well known in the art. In another embodiment, the software instructions may also be downloaded over a wireless connection. A computer program propagated signal product **82** embodied on a propagated signal on a propagation medium (e.g., a radio wave, an infrared wave, a laser wave, a sound wave, or an electrical wave propagated over the Internet or other network) provides software instructions for the gateway application **74** or any of its components (see **FIG. 4**). In alternate embodiments, the propagated signal is an analog carrier wave or digital signal carried on the propagated medium. For example, the propagated signal may be a digitized signal propagated over the Internet or other network. In one embodiment, the propagated signal is a signal that is transmitted over the propagation medium over a period of time, such as the instructions for a software application sent in packets over a network over a period of milliseconds, seconds, minutes, or longer. In another embodiment, the computer readable medium of the computer program product **80** is a propagation medium that the computer may receive and read, such as by receiving the propagation medium and identifying a propagated signal embodied in the propagation medium, as described above for the computer program propagated signal product **82**.

[**0042**] **FIG. 5** illustrates an example of a device database **72** suitable for use with the gateway server **22** of **FIG. 4**. The device database **72** includes device identifiers **76-1**, **76-2**, and **76-3**. The device identifier **76** is a unique identifier or address for the mobile device **28**, such as unique unit identifier for a particular device, a MAC (Media Access Control) address, other network address, or other identification information that uniquely identifies a particular mobile device **28** from any other mobile device **28**. The context information **56** includes IP addresses **88** (e.g., **88-1**, **88-2**, and **88-3**) and pointers to cluster information **90** (e.g.,

90-1, **90-2**, and **90-3**). Each IP address **88** (e.g., **88-1**, **88-2**, and **88-3**) and pointer to cluster information **90** (e.g., **90-1**, **90-2**, and **90-3**) are associated with a device identifier **76** (e.g., **76-1**, **76-2**, and **76-3**). The term "pointer to cluster information" uses the term "pointer" in a general sense to indicate a pointer, reference, address, or other indication of where the cluster information **96** is located. Generally, the cluster information **96** may be obtained on a cluster information database **94** associated with the gateway server **22**, or in a cluster information database **94** associated with another server, computer, or data server, as will be discussed in more detail later.

[**0043**] The device database **72** also stores user identification information **92** (e.g., **92-1**, **92-2**, and **92-3**) associated with each device ID **76** (e.g., **76-1**, **76-2**, and **76-3**), as shown in **FIG. 5**. The user identification information **92** includes information identifying or related to a user of a mobile device **28**, such as a unique user identifier or a user PIN (Personal Identity Number). The user identification information **92** may also include other user information, such as the user service level (e.g., allocated WLAN bandwidth) if such information is not determined by the cluster access privileges **46**. In one embodiment, the user identification information **92** is used by the gateway server **22** but not necessarily stored or retained in the device database **72** after it is used.

[**0044**] **FIG. 6** illustrates a procedure for authorizing access based on cluster access privileges **46**. In step **200**, the security server identifies users that belong to a cluster (e.g., perform similar roles in an organization). Typically, membership in a cluster reflects a role in an organization such as an accountant in a business or a student in a university. For example, students majoring or taking courses in history at a university are members of a history cluster, and students majoring or taking courses in engineering are members of an engineering cluster. In one embodiment, cluster information **96** (that indicates the members of a cluster and the corresponding cluster access privileges **46** for all members of the cluster) are stored on the gateway server **22**. In another embodiment, the cluster information **96** and cluster access privileges **46** are stored in a cluster information server separate from the gateway server **22**. For example, the information for the history cluster may be stored in a history server (i.e., server computer providing database and other support to the history department). The pointer to the cluster information **90** (as shown in **FIG. 5**) thus points to a database on the history server having the cluster information **96** and access privileges **46** for the cluster of history students.

[**0045**] In step **202**, the gateway server **22** sets access privileges **46** to a resource for a cluster of users in a WLAN. In one embodiment, the gateway server **22** sets the access privileges **46** based on input from an operator. For example, an operator in a history department sets the access privileges **46** for the history cluster of students by entering data at a keyboard at the history server. In such a case, the access privileges **46** may include access to databases of course materials and reference materials in the history server (but not to allow access to course materials and reference materials on databases on servers of other department's computers). The history server is one example of a resource **44**. Furthermore, access privileges **46** may specify a bandwidth allocation on the WLAN for each mobile device **28** used by a member of the history cluster that may be different for the bandwidth allocation on the WLAN for mobiles devices of students in other clusters, such as the engineering cluster.

[**0046**] In step **204**, the gateway server **22** receives a request from a mobile device **28** controlled by a user who is a member of a cluster to access the resource **44-2**. The request includes a user identifier **92** and a device identifier **76**. Typically, the request originates from a mobile device **28** to the LAP base station **24**, which then passes on the request (as an authentication request) to the gateway server **22**.

[**0047**] In step **206**, the gateway server **22** locates access privileges **46** based on the device identifier **76**, user identifier **92**, and the cluster information **96**. As described earlier, the cluster information **96** may be stored in a cluster information database **94** associated with the gateway server **22** or another server.

[**0048**] In step **208**, the gateway server **22** authorizes a current session over the WLAN between the mobile device **28** and the resource **44** based on the access privileges **46**. For example, the gateway server **22** authorizes access to databases on a particular server, such as the history department server, and/or authorizes a certain level of WLAN bandwidth to be allocated to the mobile device **28** that originated the request.

[**0049**] **FIG. 7** illustrates a procedure for managing context information **56** in a WLAN. In step **300**, the gateway server **22** authorizes an initial session from a user's mobile device **28** over a WLAN to a resource **44**. Typically, the mobile device **28** is then able to communicate with the resource through a networked system, such as the networked system **50** shown in **FIG. 2**.

[**0050**] In step **302**, the gateway server **22** provides a context for the session (e.g., allocates an IP address **88** for use by the device **28**). For example, the gateway server **22** dynamically allocates an IP address **88** for use by the mobile device **28** or requests such an allocation from a DHCP (Dynamic Host Configuration Protocol) server. The gateway server **22** may also allocate or specify other information, such as configuration information for the session or the connection **40**.

[**0051**] In step **304**, the gateway server **22** saves the context information **56** for the session (e.g., IP address **88** and other information) based on the device identifier **76**, after a disconnection that interrupts the session between the mobile device **28** and the resource **44**. For example, the user moves the mobile device **28** from one location to another, as from a conference room to an office, as shown in **FIG. 2**. The gateway server **22** stores the IP address **88** in a device database **72** and associates the IP address **88** with the device identifier **76** of the mobile device **28**.

[**0052**] In step **306**, the gateway server **22** receives a request (including device identifier **76**) to access the resource **44** from the mobile device **28** over the WLAN. For example, the user moves the mobile device **28-2** from a conference room to an office out of range of the conference room LAP **24-1** (as shown in **FIG. 2**), where the mobile device **28-2** comes within range of an office LAP **24-2**. Through Bluetooth (or other WLAN protocol) inquiry mode, the mobile device **28-2** seeks to establish a connection with the office LAP **24-2** and obtain renewed access to the resource **44**. The office LAP **24-2** communicates with the

gateway server **22**, providing the request for the mobile device **28-2** to access the resource **44**.

[**0053**] In step **308**, the gateway server **22** locates the context information **56** (e.g., IP address **88**) associated with the device identifier **76** for the initial session between the mobile device **28** and the resource **44**. For example, the gateway server **22** looks up the context information **56** in the device database **72** associated with the gateway server **22** and locates the IP address **88-2** associated with a specific mobile device **28-2**, as well as other information such as the pointer to the cluster information **90-2** if needed.

[**0054**] In step **310**, the gateway server **22** provides the context information **56** (e.g., IP address **88**) for use in the current session between the mobile device **28** and the resource **44**. For example, the gateway server **22** retrieves the IP address **88-2** associated with the mobile device **28-2** from the device database **72** and reassigns the IP address **88-2** to the mobile device **28-2**.

[**0055**] The gateway server **22** may also serve as a centralized security server or clearinghouse (or provide a connection) to such a central server. Such a central security server provides context information **56** (e.g., IP address **88**) to different providers of WLAN services. The providers use the context information **56** directly or provides it to local security servers **22** so that users of mobile device may roam to WLAN's provided by different service providers while retaining context information **56** such as an IP address **88** allocated to the mobile device during initial session or connection **40** to a WLAN.

[**0056**] In a preferred embodiment, in which the device identifier **76** is based on a MAC address for the mobile device, the gateway server **22** is a conventional RADIUS server that is extended so that it contains a version of the MAC to IP address cache (e.g., device database **72**) that is used by the gateway application **74** to map MAC addresses to IP addresses. In the preferred embodiment, the gateway server **22** recognizes the unique device identifier **76** (in this case the MAC address) and re-assigns the same IP address **88** and configuration. It upgrades the user location, as described in more detail below.

[**0057**] When a mobile device **28** moves to a new subnet, the newly associated LAP **24** starts to answer for the MAC address of the mobile device **28**, and also to send out packets to the gateway server **22** with the MAC address of the mobile device. In this case the gateway server **22** is actually a combined router and RADIUS server, as shown in **FIG. 4** (perhaps with a centralized database).

[**0058**] In another preferred embodiment, the RADIUS functionality is implemented as a separate RADIUS server that includes the device database **72** (with device identifiers **76** based on the MAC address and corresponding IP addresses **88**), and the gateway server **22** hosts and executes the gateway application **74**. In this embodiment, the gateway server **22** detects that the packet comes from a mobile device **28** whose MAC address is not part of its subnet cache, and so looks it up in the RADIUS server MAC to IP table (e.g., device database **72**). Once found it enters it in its local cache, and updates the RADIUS server with the new location. It also informs the previous gateway server **22** that manages the subnet for the previous connection of the mobile device **28** that the mobile device **28** has moved. The previous gateway server **22** then alerts its routing table so that packets addressed to that IP address **88** are forwarded to the new gateway server **22** for delivery to the mobile device **28**.

[**0059**] **FIG. 8** illustrates a networked system **100** in a WLAN environment with multiple channels. **FIG. 8** illustrates a gateway server **22** with a connection to the Internet **38**, and connections to two base station LAP's **24-3** and **24-4**, which have connections **40-7** and **40-8** to user mobile devices **28-4** and **28-5**. Mobile device **28-4** is part of scatternet **1021** and mobile device **28-5** is part of scatternet **102-2**. The scatternet **102** is a WLAN channel, such as a Bluetooth scatternet. A scatternet **102** is made up of piconets connected together by a data relay that transfers data packets between piconets so as to transfer the data packets between the mobile device **28** and the LAP **24**. Scatternets **102** enable one shared channel of a Bluetooth network to cover a larger physical area. In the IEEE 802.11 protocol the same concept applies, but the term channel is applied in place of piconet, and scatternets **102** can be built by linking IEEE 802.11 channels together using a relay device. The invention is described in terms of scatternets **102** but also works in a piconet because a piconet is the most simple implementation of a scattemet **102**. Each scatternet **102-1** and **102-2** may have a larger number of users than is shown is **FIG. 8**, which shows only one representative mobile device **28-4** or **28-5** per scatternet **102 -1** or **102-2**.

[**0060**] In a crowded environment such as a conference room there may well be multiple devices **28** desiring high speed WLAN access. Maximum asymmetric capacity per scatternet **102** (e.g., Bluetooth scatternet) is 721 kbps up (or down) and 56kbps up (or down) but this is split between the seven active users (for a scatternet **102** that is limited to this number of users). In Bluetooth, a scatternet **102** is two or more channels (Bluetooth piconets) co-located in the same area. Symmetric mode gives 460 kbps in each direction. Operating **10** scattemets **102** in the same location only reduces throughput per scattemet **102** to around 650 kbps, so for best performance users should be spread between scatternets **102**. Users should also be assigned to symmetric or asymmetric scatternets **102** according to their traffic pattern. They can also obtain faster speeds (1.4 Mbps) by being assigned multiple parallel channels using multi-channel (as used for ISDN).

[**0061**] Users can choose which scattemet **102** to join by signaling busy scatternets **102** via the loading variable in the SDP (service discovery protocol). Users can be directed to join a particular scatternet **102** by signaling "busy" scatternet **102** via the loading variable in the radio protocol header. Not all users may pay attention, and it may be desirable to introduce different levels of service for different users.

[**0062**] In operation, the mobile device **28** requests service from a LAP **24** by sending a request along with its device address (e.g., device identifier **76**). The LAP **24** (which is a scatternet master) would normally simply respond by paging the device **28** and starting the synchronization. Instead, in the present invention, the LAP **24** passes the request along with the device address (i.e., device identifier **76**) back to the gateway server **22** which looks up the user's service level **104** and the loading on each of the relevant scattemets **102** in accordance with the procedure illustrated in **FIG. 6**. The user's service level **104** is an example of a cluster access privilege **46** or context information **56**. The gateway server

22 then signals to the appropriate LAP **24** to page the device **28** (this may not be the LAP **24** that received the request).

[**0063**] When a mobile device **28** has mobile radio interfaces (that is, both a Bluetooth interface and a 802.11b interface) or can participate in one of a number of overlapping channels (which is the general case of a scattemet **102**), then when the mobile device **28** moves to a new channel and starts to send packets, the gateway server **22** looks up the device **28** in the device database **72**, and according to the user service level and scattemet loading (e.g., traffic or congestion on the subnet that the mobile device is connected to) might decide that the mobile device **28** should be communicating via another channel that is covering that mobile device **28**. The mobile device **28** may be directed to a different channel (e.g., Bluetooth piconet) within a scatternet **102**, or to a different scatternet **102**. In that case the mobile device **28** is forced to transfer its connection **40**. For example, mobile device **28-4** is seeking to make a new connection to one of the scatternets **102-1** or **102-2** in **FIG. 8**. First the mobile device **28-4** seeks to make a connection to congested scatternet **102-2**. The gateway server **22** thus directs the mobile device **28-4** to join a less congested scatternet **102-1**, with the result shown by connection **40-7** in **FIG. 8**. Subsequently, mobile device **28-4** access to resources **44** is provided without requiring re-registration with the gateway server **22**, following the procedure of **FIG. 7**.

[**0064**] **FIG. 9** illustrates a networked system **110** in a WLAN environment with a gateway server **22** and a home server **112**. The home server **112** is a network (e.g., Internet) server computer that provides authentication services, such as RADIUS authentication services, for a user with a mobile device **28** seeking access to a resource **44-2** available on the networked system **110**. The home server **112** functions as a home or base server for the user of the mobile device **28**, and may provide cluster information or context information **56** (as described previously).

[**0065**] In an example of using a home server **112**, the user of a mobile device **28** first initiates a log on to a remote network, and indicates a desire to use restricted or "for charge" resources **44-2**. The mobile device **28** starts an authentication session with the local gateway server **22**. The mobile device **28** supplies the name of the home server **112** as part of the user identification during the authentication process (e.g., *user@kradius***5**.employer.com). The local gateway server **22** authenticates the user with the user's home server **112**, passing back to the home server **112** the location (base station LAP **24** and network), IP address, and billing information.

[**0066**] This completes the registration of the mobile device **28** with the home server **112**, which stores the mobile device **28** IP address and location of the mobile device **28**. The user (i.e., device owner) may also set up a list of preferences indicating who is allowed to know the location of the mobile device **28** and which messages are allowed to be forwarded to the mobile device **28**.

[**0067**] In one embodiment, the home server **112** (or other central authentication server) can act as a central roaming clearing house for companies and Bluetooth (or other wireless protocol) ISP's that provide WLAN services. The WLAN operator then needs only have one authentication and billing agreement with the central server (e.g., home server **112**). Users are billed by their home network provider (e.g., ISP or corporation). Users that do not have a "home" who wish to use a free service (e.g., Internet access) can register with the central or home server **112** so that they can be authenticated but not charged.

[**0068**] While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

What is claimed is:

1. A method for authorizing access by a user to a resource over a wireless local area network, comprising the steps of:

setting access privileges to the resource for a cluster of users of the wireless local area network;

receiving a request from a device controlled by the user to access the resource over the wireless local area network, the user having a membership in the cluster, and the request including a user identifier for the user and a device identifier for the device making the request;

locating access privileges based on the device identifier, the user identifier, and the cluster; and

authorizing a current session between the device and the resource based on the located access privileges.

2. A system comprising a digital processor for authorizing access by a user to a resource over a wireless local area network, the system comprising:

a gateway application executing on the digital processor for setting access privileges to the resource for a cluster of users of the wireless local area network; and

a communications interface coupled with the digital processor for receiving a request from a device controlled by the user to access the resource over the wireless local area network, the user having a membership in the cluster, and the request including a user identifier for the user and a device identifier for the device making the request,

the gateway application being responsive to the received request and locating access privileges based on the device identifier, the user identifier, and the cluster and the gateway application authorizing a current session between the device and the resource based on the located access privileges.

3. A computer program product that includes a computer usable medium having computer program instructions stored thereon for authorizing access by a user to a resource over a wireless local area network, such that the computer program instructions, when performed by a digital processor, cause the digital processor to:

set access privileges to the resource for a cluster of users of the wireless local area network;

receive a request from a device controlled by the user to access the resource over the wireless local area network, the user having a membership in the cluster, and the request including a user identifier for the user and a device identifier for the device making the request;

locate access privileges based on the device identifier, the user identifier, and the cluster; and

authorize a current session between the device and the resource based on the located access privileges.

4. A method for managing context information for a wireless local area network, comprising the steps of:

receiving a request to access the resource over the wireless local area network, the request including a device identifier for a device making the request;

locating context information associated with the device identifier, the context information associated with a previous session between the device and the resource; and

providing the context information for use in a current session between the device and the resource.

5. The method of claim 4, wherein the wireless local area network is based on a radio frequency suitable for use in local wireless communications.

6. The method of claim 4, wherein communications over the wireless local area network are based on a spread-spectrum technique based on a carrier frequency greater than about 2,000 megahertz.

7. The method of claim 4, wherein the device identifier is a unique identification number.

8. The method of claim 4, wherein the context information includes an internet protocol address assigned to the device in the previous secure session.

9. The method of claim 4, wherein the context information includes cluster information associated with a user of the device for the current session, the user having a membership in the cluster, and the cluster information providing access privileges associated with a member of the cluster who set the access privileges for the cluster in a previous request to access the resource.

10. The method of claim 4, wherein the device is a voice-enabled communications device, and the gateway server is adapted for voice-enabled network communications.

11. A system comprising a digital processor for managing context information for a wireless local area network, the system comprising:

a communications interface coupled with the digital processor for receiving a request to access the resource over the wireless local area network, the request including a device identifier for a device making the request; and

a gateway application executing on the digital processor, in response to the received request, the gateway application locating context information associated with the device identifier, the context information associated with a previous session between the device and the resource, and providing the context information for use in a current session between the device and the resource.

12. The system of claim 11, wherein the wireless local area network is based on a radio frequency suitable for use in local wireless communications.

13. The system of claim 11, wherein communications over the wireless local area network are based on a spread-spectrum technique based on a carrier frequency greater than about 2,000 megahertz.

14. The system of claim 11, wherein the device identifier is a unique identification number.

15. The system of claim 11, wherein the context information includes an internet protocol address assigned to the device in the previous secure session.

16. The system of claim 11, wherein the context information includes cluster information associated with a user of the device for the current session, the user having a membership in the cluster, and the cluster information providing access privileges associated with a member of the cluster who set the access privileges for the cluster in a previous request to access the resource.

17. The system of claim 11, wherein the device is a voice-enabled communications device, and the gateway server is adapted for voice-enabled network communications.

18. A computer program product that includes a computer usable medium having computer program instructions stored thereon for managing context information for a wireless local area network, such that the computer program instructions, when performed by a digital processor, cause the digital processor to:

receive a request to access the resource over the wireless local area network, the request including a device identifier for a device making the request;

locate context information associated with the device identifier, the context information associated with a previous session between the device and the resource; and

provide the context information for use in a current session between the device and the resource.

19. A method for balancing a load among a plurality of wireless subnetworks, comprising the steps of:

receiving an indication that a device has established a first connection with a first wireless subnetwork, the device having a device identifier;

determining a user service level associated with the device based on the device identifier and based on a load level for the first wireless subnetwork in comparison to load levels associated with each of the other wireless subnetworks available for connection by the device; and

if a second connection provides a preferable balancing of load levels among the wireless subnetworks, then directing the device to establish the second connection with a second wireless subnetwork based on the determined user service level and the load level of the first wireless subnetwork,

20. A system comprising a digital processor for balancing a load among a plurality of wireless subnetworks, the system comprising:

a communications interface coupled with the digital processor for receiving an indication that a device has established a first connection with a first wireless subnetwork, the device having a device identifier; and

a gateway application executing on the digital processor for determining a user service level associated with the device based on the device identifier and based on a load level for the first wireless subnetwork in comparison to load levels associated with each of the other

wireless subnetworks available for connection by the device, and in response to a second connection providing a preferable balancing of the load levels among the wireless subnetworks, the gateway application directing the device to establish a second connection with a second wireless subnetwork based on the user service level and the load level of the first wireless subnetwork.

21. A computer program product that includes a computer usable medium having computer program instructions stored thereon for balancing load among a plurality of wireless subnetworks, such that the computer program instructions, when performed by a digital processor, cause the digital processor to:

receive an indication that a device has established a first connection with a first wireless subnetwork, the device having a device identifier;

determine a user service level associated with the device based on the device identifier and based on a load level for the first wireless subnetwork in comparison to load levels associated with each of the other wireless subnetworks available for connection by the device; and

direct the device to establish a second connection with a second wireless subnetwork based on the user service level and the load level of the first wireless subnetwork, if the second connection provides a preferable balancing of load levels among the wireless subnetworks.

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