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(54) **PERSONNEL AND ASSET TRACKING METHOD AND APPARATUS**

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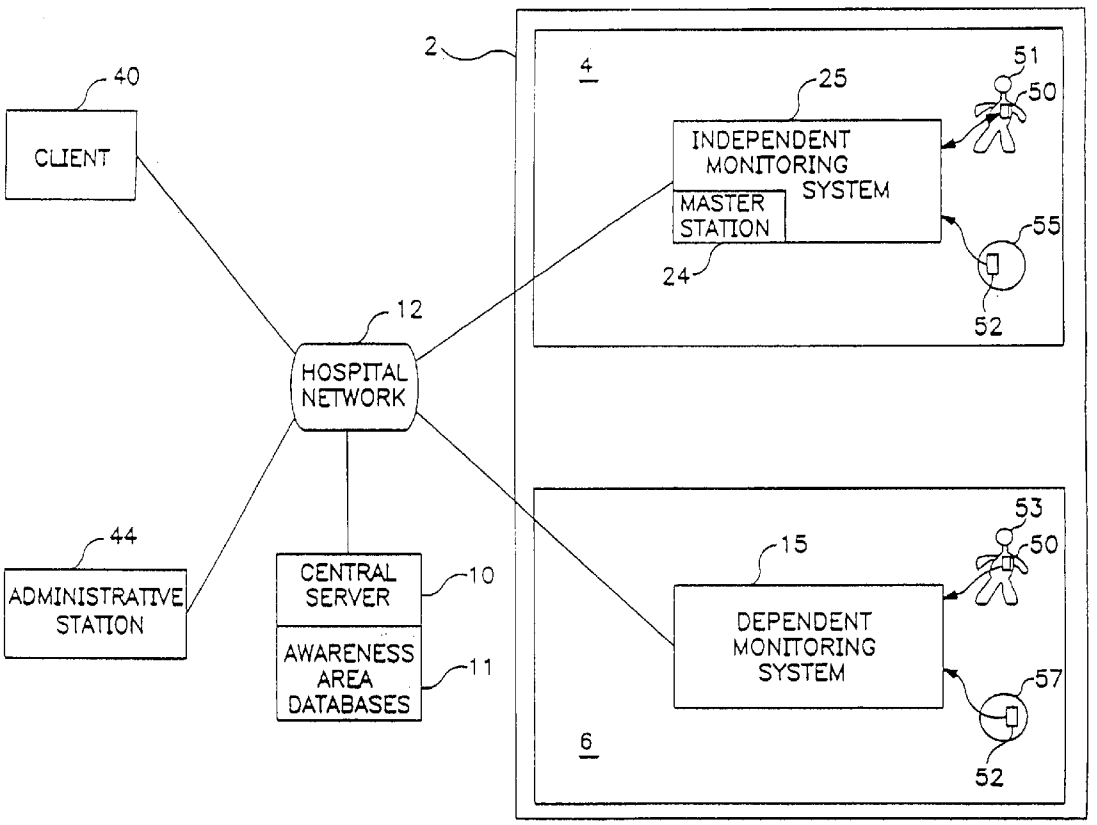
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(52) **U.S. Cl.** **340/539.13**; 340/825.49; 235/385

(57) **ABSTRACT**

A method for processing messages in a system for locating and tracking tags within an area is provided. Each tag includes a transmitter configured to transmit a unique identifier periodically. Location messages are received and processed by at least one monitoring system to determine whether a tag has changed location.



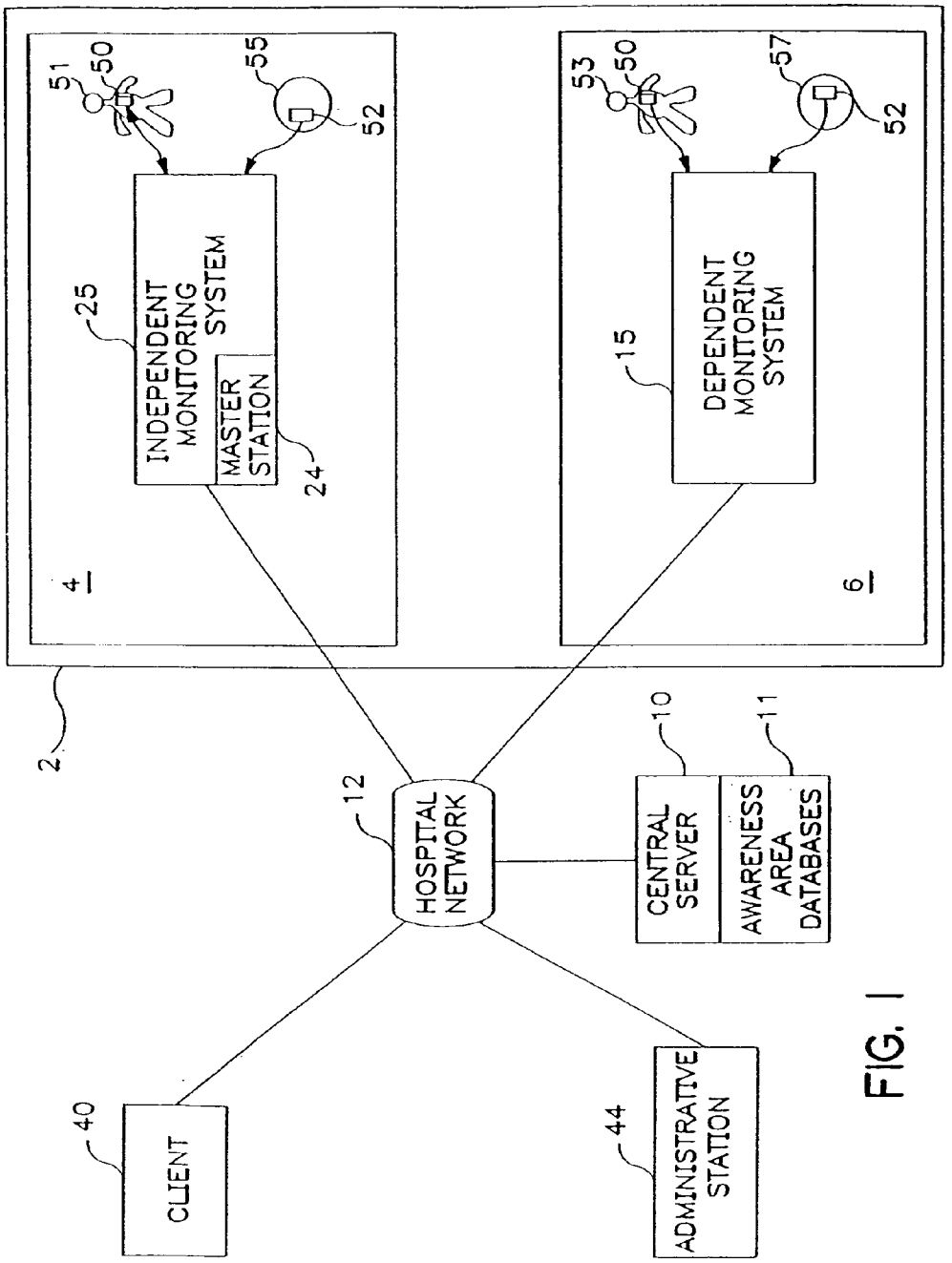

51
50
55
52
INDEPENDENT MONITORING SYSTEM
25
MASTER STATION
24
4
53
50
57
52
DEPENDENT MONITORING SYSTEM
15
6
2
12
HOSPITAL NETWORK
10
CENTRAL SERVER
11
AWARENESS AREA DATABASES
40
CLIENT
44
ADMINISTRATIVE STATION

FIG. 1

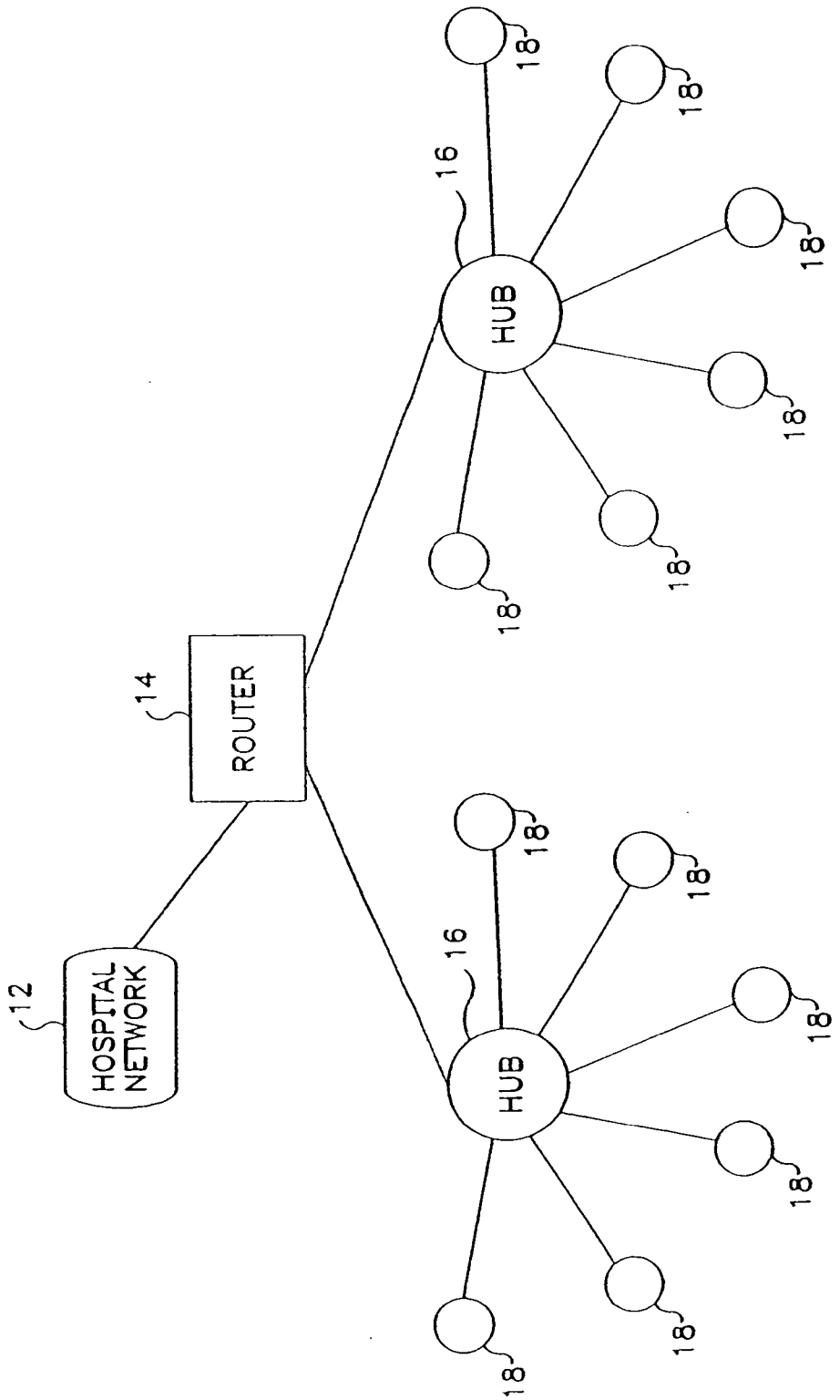

HOSPITAL NETWORK
12
ROUTER
14
HUB
16
HUB
16
18
18
18
18
18
18
18
18
18
18
18
18

FIG. 2

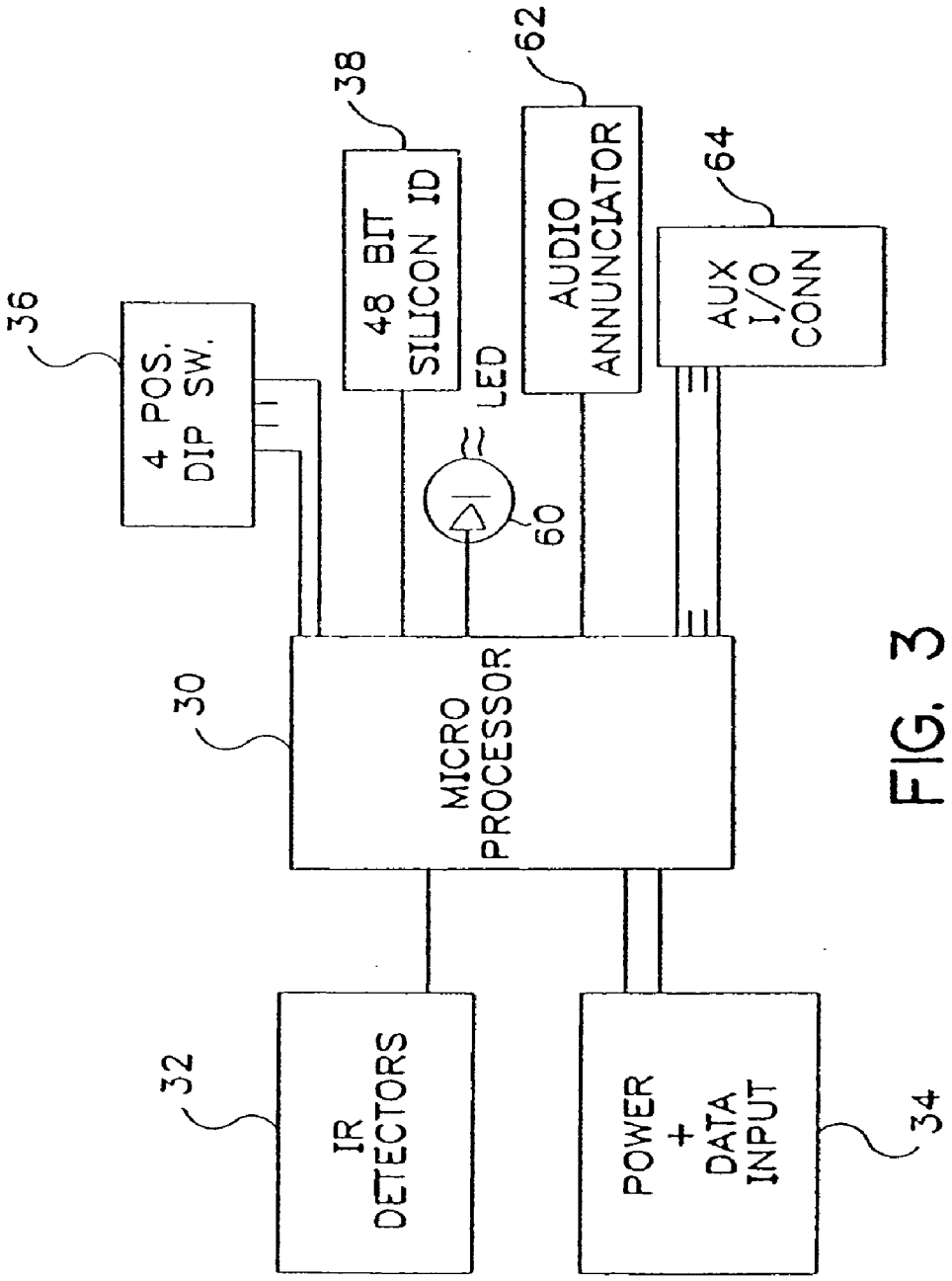

36
4 POS. DIP SW.
38
48 BIT SILICON ID
62
AUDIO ANNUNCIATOR
64
AUX I/O CONN
LED
60
30
MICRO PROCESSOR
32
IR DETECTORS
POWER + DATA INPUT
34

FIG. 3

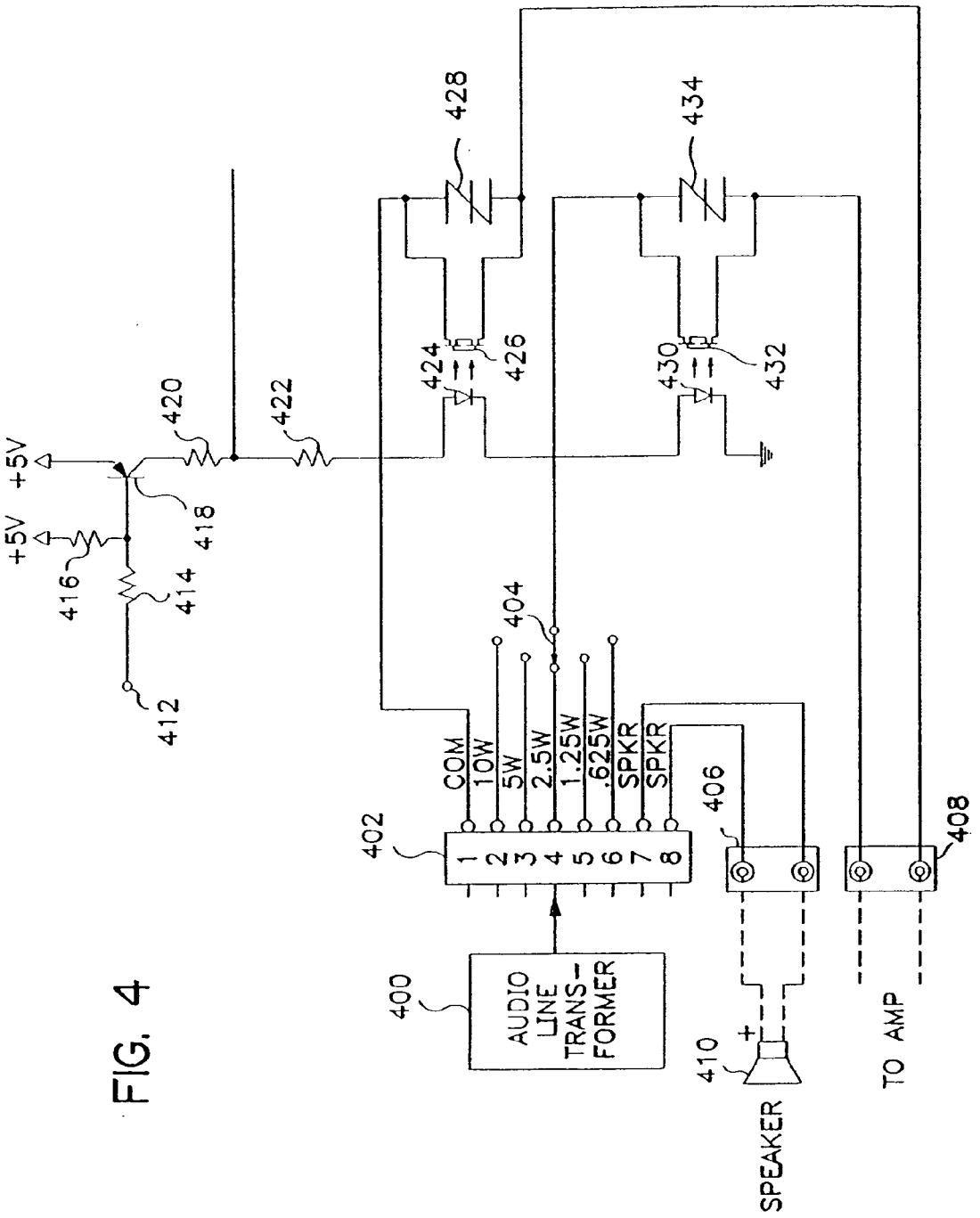

+5V
+5V
412
414
416
418
420
422
424
426
428
430
432
434
404
COM
10W
5W
2.5W
1.25W
.625W
SPKR
SPKR
402
1
2
3
4
5
6
7
8
406
408
400
AUDIO LINE TRANS-FORMER
410
SPEAKER
TO AMP

FIG. 4

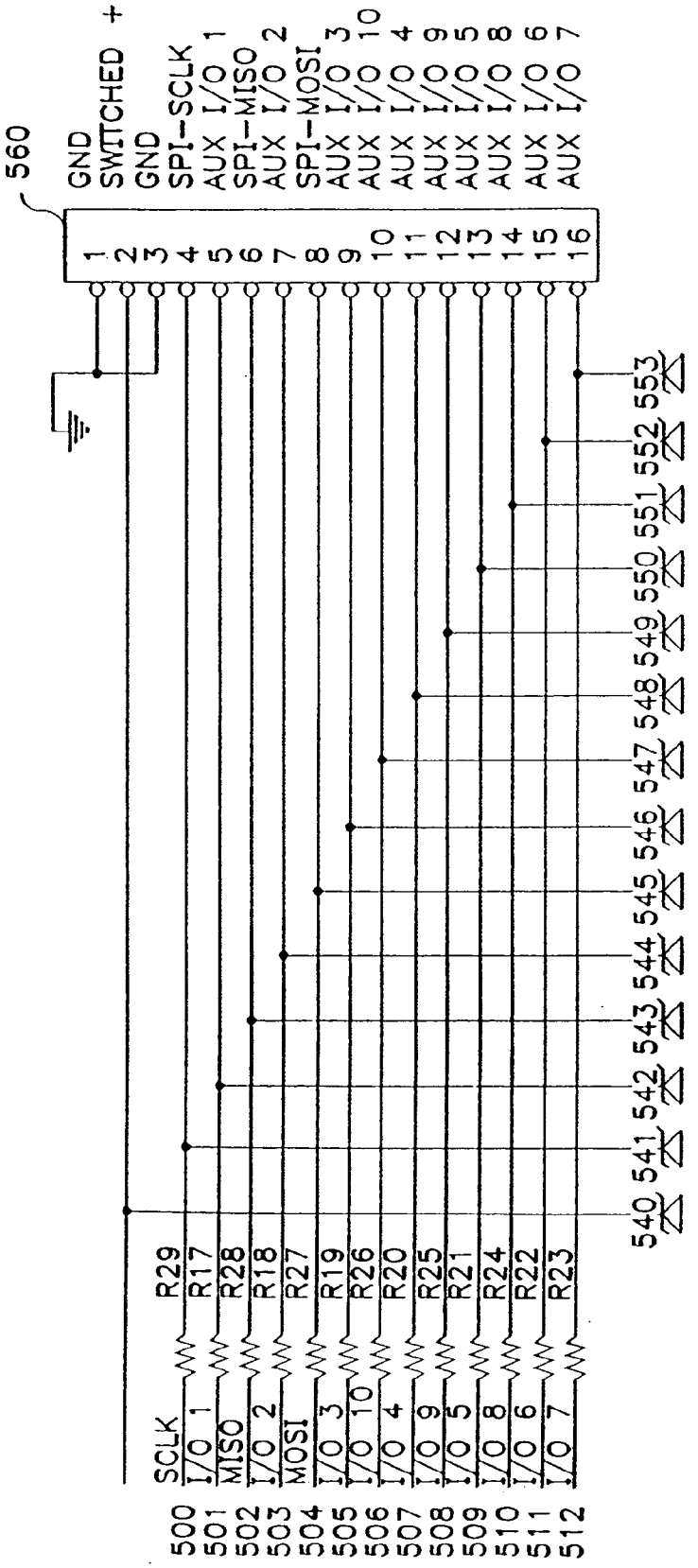

560
GND
SWITCHED +
GND
SPI-SCLK
AUX I/O 1
SPI-MISO
AUX I/O 2
SPI-MOSI
AUX I/O 3
AUX I/O 10
AUX I/O 4
AUX I/O 9
AUX I/O 5
AUX I/O 8
AUX I/O 6
AUX I/O 7
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
SCLK
I/O 1
MISO
I/O 2
MOSI
I/O 3
I/O 10
I/O 4
I/O 9
I/O 5
I/O 8
I/O 6
I/O 7
R29
R17
R28
R18
R27
R19
R26
R20
R25
R21
R24
R22
R23
500 501 502 503 504 505 506 507 508 509 510 511 512
540 541 542 543 544 545 546 547 548 549 550 551 552 553

FIG. 5

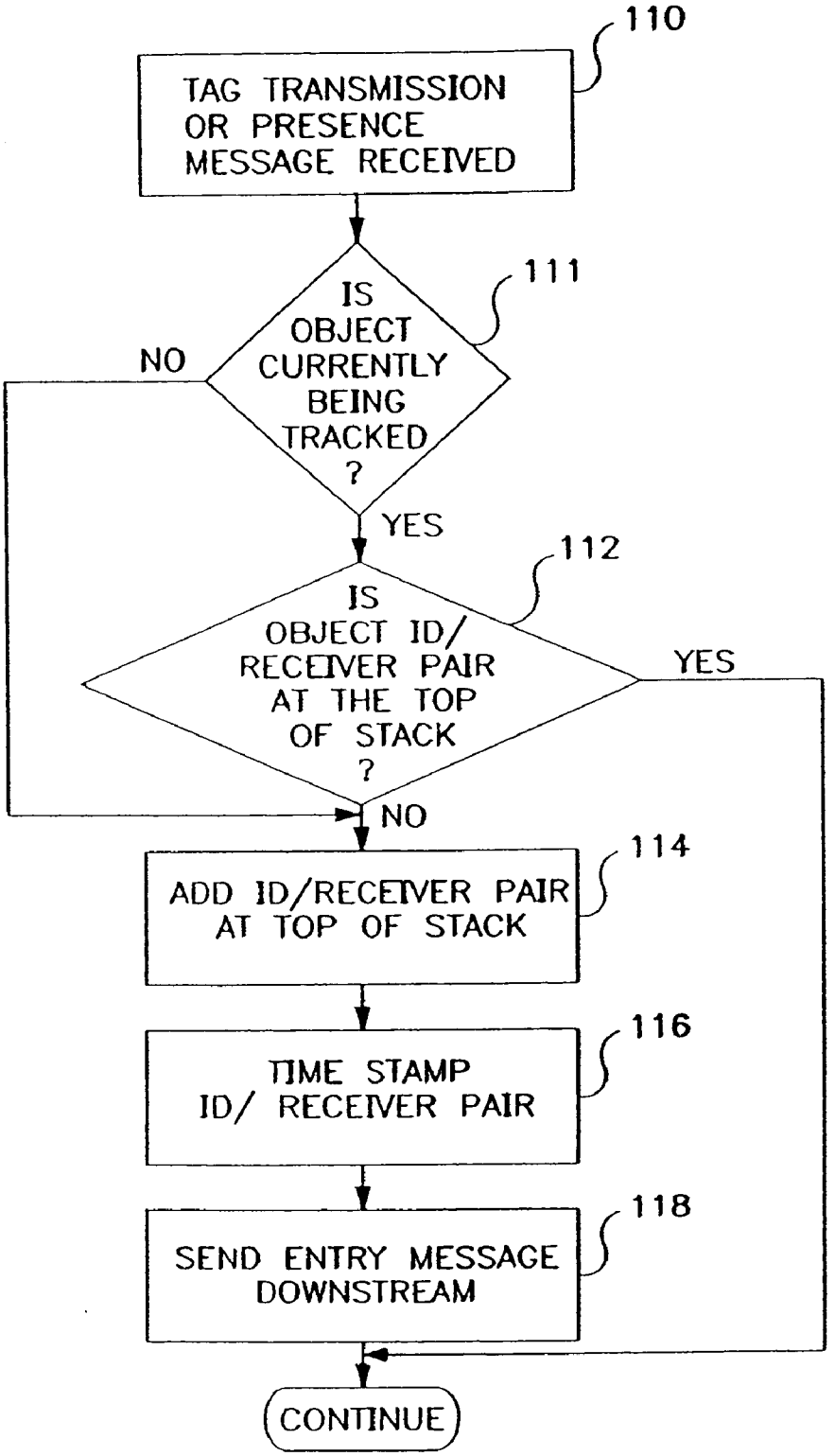

110
TAG TRANSMISSION OR PRESENCE MESSAGE RECEIVED
111
IS OBJECT CURRENTLY BEING TRACKED ?
NO
YES
112
IS OBJECT ID/ RECEIVER PAIR AT THE TOP OF STACK ?
YES
NO
114
ADD ID/RECEIVER PAIR AT TOP OF STACK
116
TIME STAMP ID/ RECEIVER PAIR
118
SEND ENTRY MESSAGE DOWNSTREAM
CONTINUE

FIG. 6

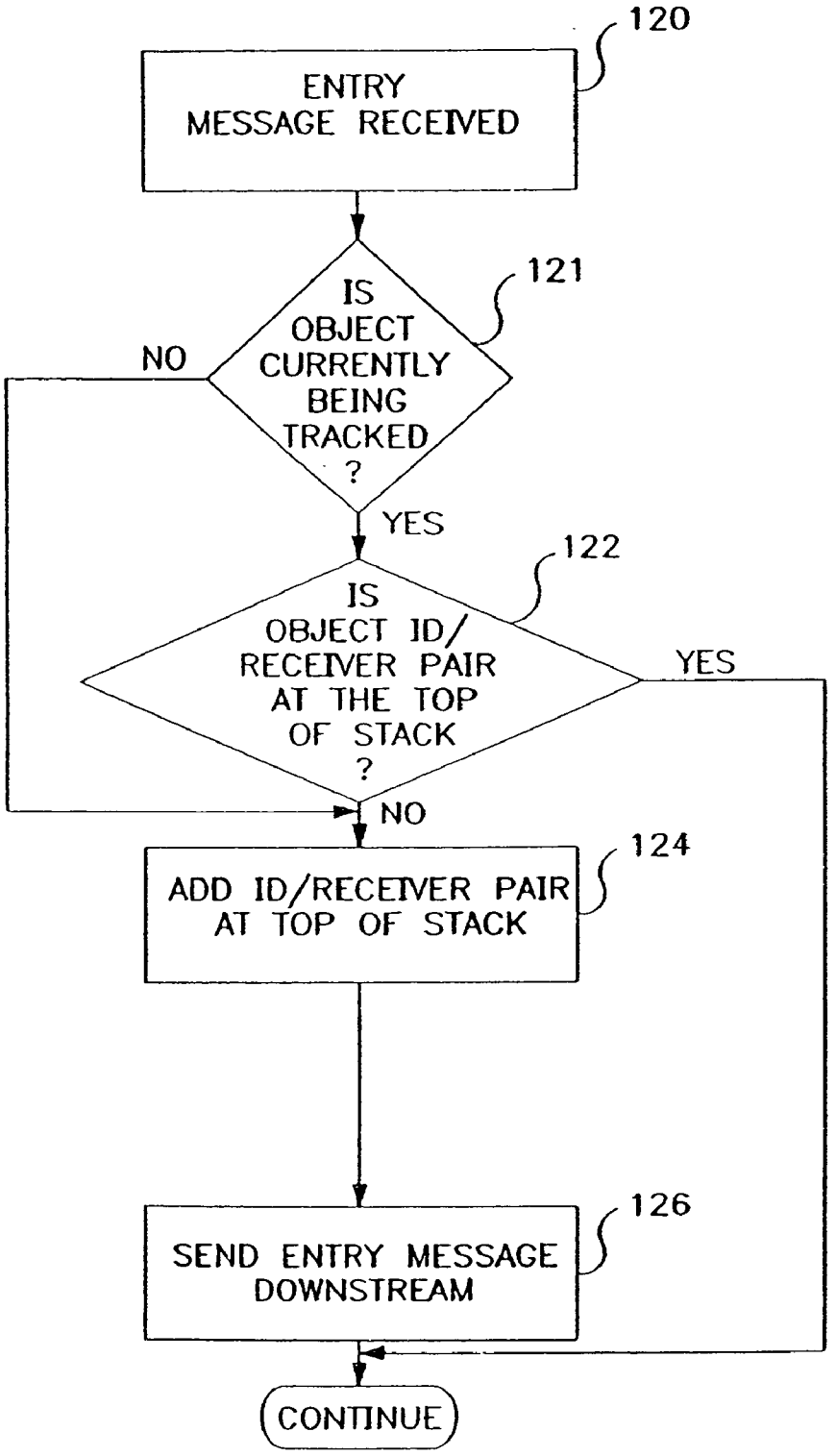

120
ENTRY MESSAGE RECEIVED
121
IS OBJECT CURRENTLY BEING TRACKED ?
NO
YES
122
IS OBJECT ID/ RECEIVER PAIR AT THE TOP OF STACK ?
YES
NO
124
ADD ID/RECEIVER PAIR AT TOP OF STACK
126
SEND ENTRY MESSAGE DOWNSTREAM
CONTINUE

FIG. 7

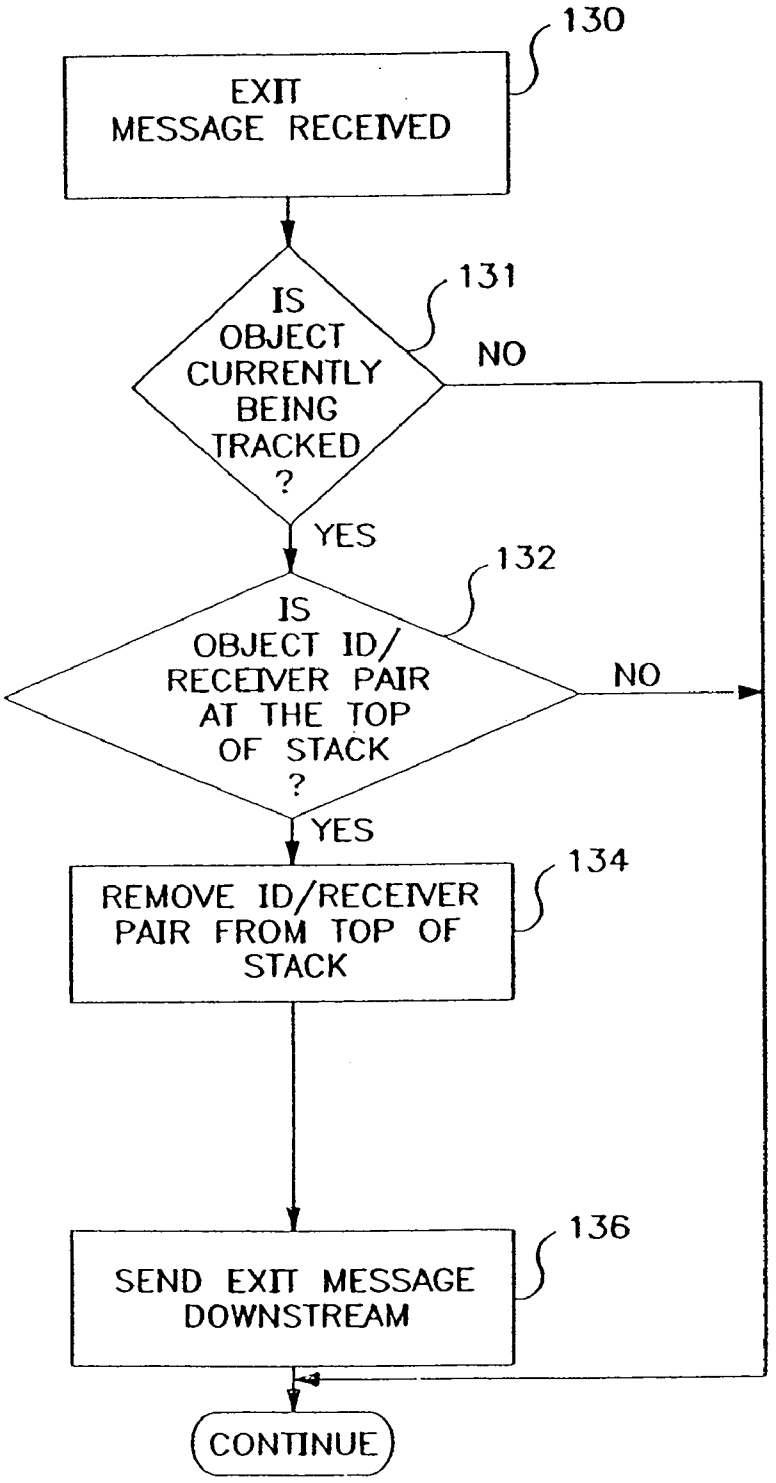

130
EXIT MESSAGE RECEIVED
131
IS OBJECT CURRENTLY BEING TRACKED ?
NO
YES
132
IS OBJECT ID/ RECEIVER PAIR AT THE TOP OF STACK ?
NO
YES
134
REMOVE ID/RECEIVER PAIR FROM TOP OF STACK
136
SEND EXIT MESSAGE DOWNSTREAM
CONTINUE

FIG. 8

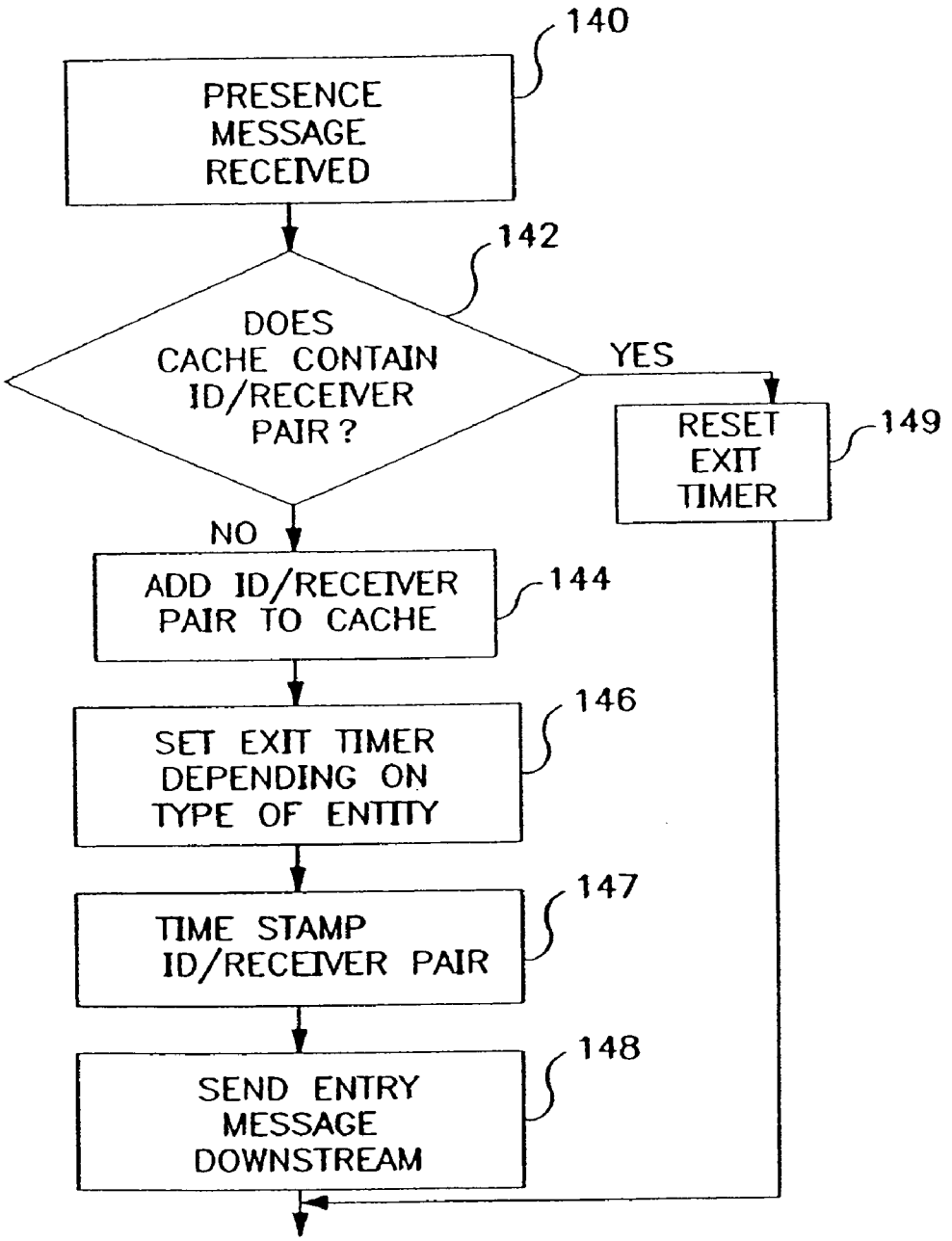

140
PRESENCE MESSAGE RECEIVED
142
DOES CACHE CONTAIN ID/RECEIVER PAIR ?
YES
NO
RESET EXIT TIMER
149
ADD ID/RECEIVER PAIR TO CACHE
144
SET EXIT TIMER DEPENDING ON TYPE OF ENTITY
146
TIME STAMP ID/RECEIVER PAIR
147
SEND ENTRY MESSAGE DOWNSTREAM
148

FIG.9

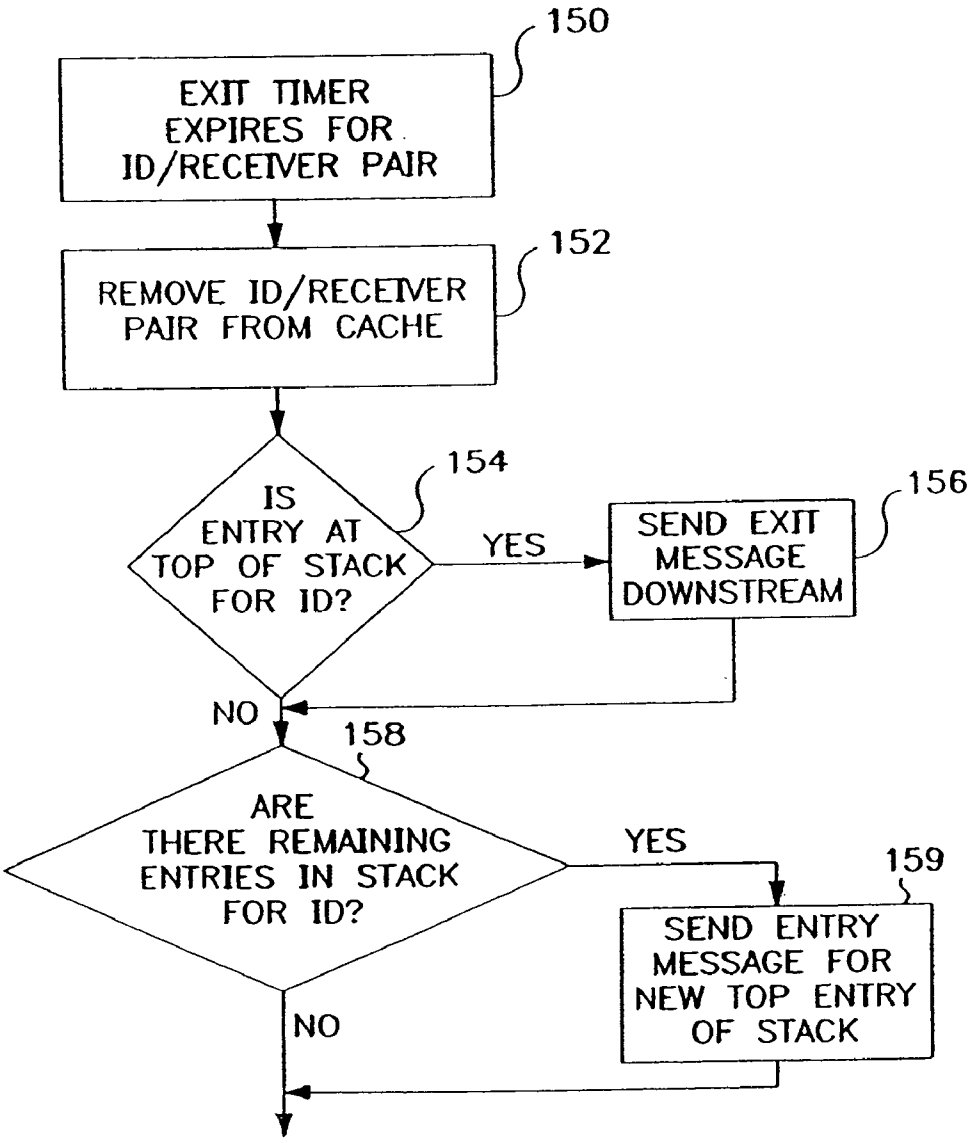

150
EXIT TIMER EXPIRES FOR ID/RECEIVER PAIR
152
REMOVE ID/RECEIVER PAIR FROM CACHE
154
IS ENTRY AT TOP OF STACK FOR ID?
YES
156
SEND EXIT MESSAGE DOWNSTREAM
NO
158
ARE THERE REMAINING ENTRIES IN STACK FOR ID?
YES
159
SEND ENTRY MESSAGE FOR NEW TOP ENTRY OF STACK
NO

FIG. 10

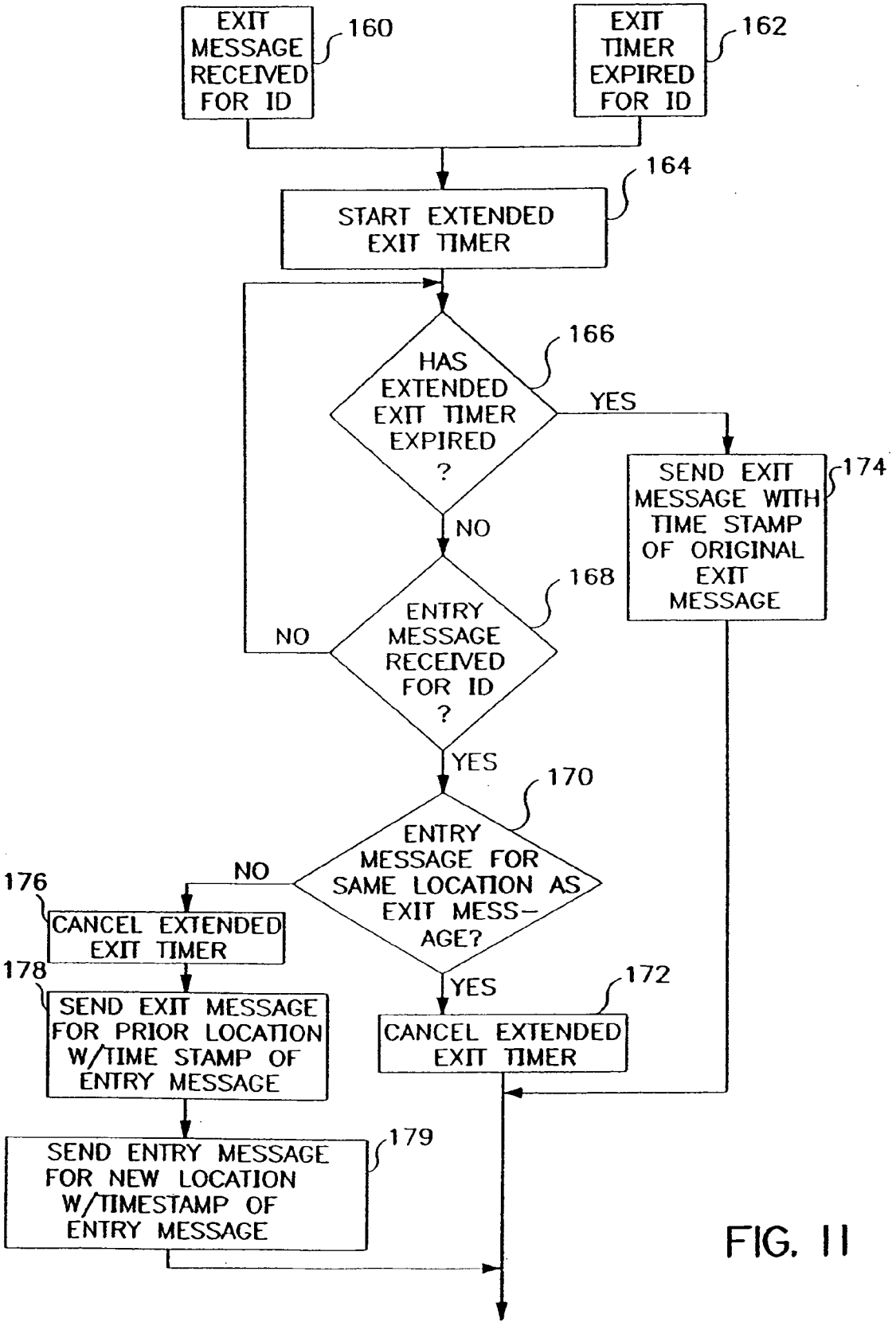

EXIT MESSAGE RECEIVED FOR ID
160
EXIT TIMER EXPIRED FOR ID
162
START EXTENDED EXIT TIMER
164
HAS EXTENDED EXIT TIMER EXPIRED ?
166
YES
NO
SEND EXIT MESSAGE WITH TIME STAMP OF ORIGINAL EXIT MESSAGE
174
ENTRY MESSAGE RECEIVED FOR ID ?
168
NO
YES
ENTRY MESSAGE FOR SAME LOCATION AS EXIT MESS-AGE?
170
NO
YES
176
CANCEL EXTENDED EXIT TIMER
178
SEND EXIT MESSAGE FOR PRIOR LOCATION W/TIME STAMP OF ENTRY MESSAGE
CANCEL EXTENDED EXIT TIMER
172
SEND ENTRY MESSAGE FOR NEW LOCATION W/TIMESTAMP OF ENTRY MESSAGE
179

FIG. 11

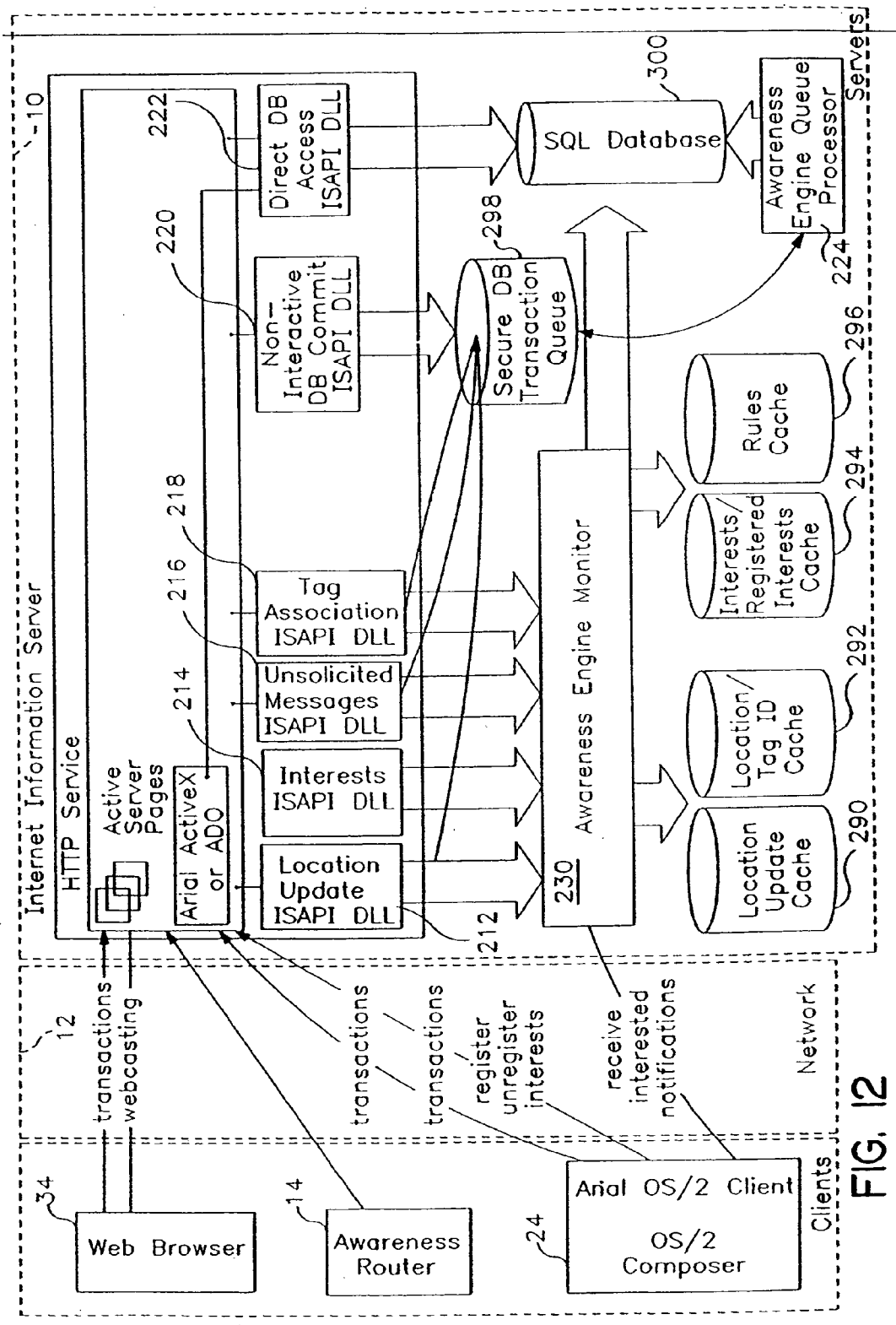

10
Internet Information Server
HTTP Service
Active Server Pages
Arial ActiveX or ADO
Direct DB Access ISAPI DLL
Non-Interactive DB Commit ISAPI DLL
Tag Association ISAPI DLL
Unsolicited Messages ISAPI DLL
Interests ISAPI DLL
Location Update ISAPI DLL
222
220
218
216
214
212
SQL Database
300
Secure DB Transaction Queue
298
Awareness Engine Queue Processor
224
Servers
Awareness Engine Monitor
230
Rules Cache
296
Interests/ Registered Interests Cache
294
Location/ Tag ID Cache
292
Location Update Cache
290
12
transactions
webcasting
transactions
transactions
register
unregister
interests
receive
interested
notifications
Network
34
Web Browser
14
Awareness Router
24
Arial OS/2 Client
OS/2 Composer
Clients

FIG. 12

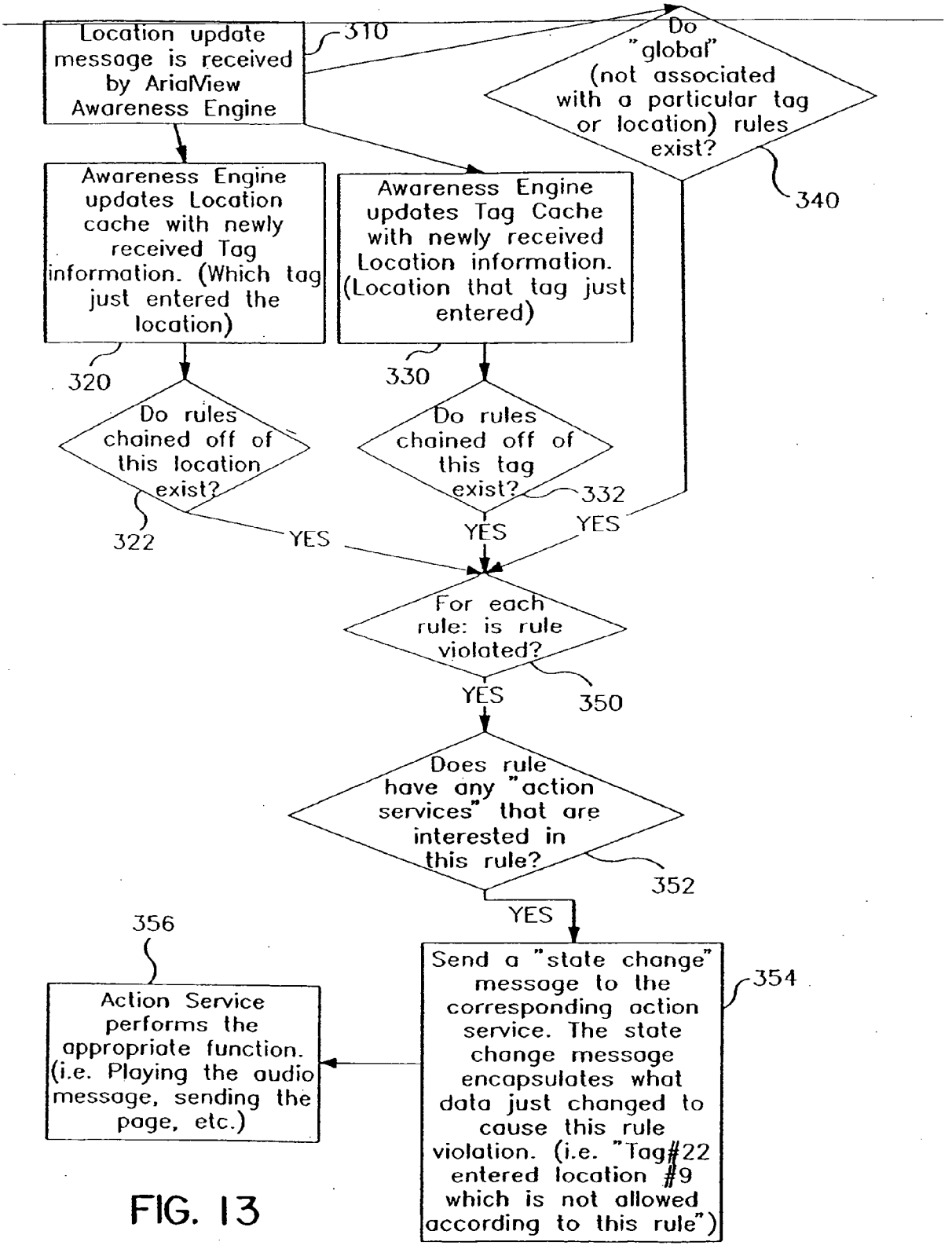

Location update message is received by AriaView Awareness Engine
310
Do "global" (not associated with a particular tag or location) rules exist?
340
Awareness Engine updates Location cache with newly received Tag information. (Which tag just entered the location)
Awareness Engine updates Tag Cache with newly received Location information. (Location that tag just entered)
320
330
Do rules chained off of this location exist?
Do rules chained off of this tag exist?
322
332
YES
YES
YES
For each rule: is rule violated?
YES
350
Does rule have any "action services" that are interested in this rule?
352
YES
356
354
Action Service performs the appropriate function. (i.e. Playing the audio message, sending the page, etc.)
Send a "state change" message to the corresponding action service. The state change message encapsulates what data just changed to cause this rule violation. (i.e. "Tag#22 entered location #9 which is not allowed according to this rule")

FIG. 13

PERSONNEL AND ASSET TRACKING METHOD AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a divisional application of U.S. patent application Ser. No. 10/265,781 filed on Oct. 7, 2002, which is a continuation of U.S. patent application Ser. No. 09/751,241 filed on Dec. 29, 2000, now U.S. Pat. No. 6,462,656, which is a continuation of U.S. patent application Ser. No. 09/479,359 filed on Jan. 7, 2000, now U.S. Pat. No. 6,344,794, which is a continuation of U.S. patent application Ser. No. 08/963,396 filed on Nov. 3, 1997, now abandoned, the disclosures of which are expressly incorporated by reference herein.

TECHNICAL FIELD OF THE INVENTION

[0002] This invention relates to a system for tracking personnel and assets over an extended area composed of one or more sub-areas which are monitored by sub-area monitoring systems. The sub-area monitoring systems communicate with and update location databases resident on a common central server. Clients communicate with and access the databases of the central server via an Internet web browser interface.

BACKGROUND OF THE INVENTION

[0003] Location and tracking systems using object tags, a plurality of receivers located at known locations and a central computer are well known in the art. The tags periodically transmit a unique ID signal which is received by the receivers and the central processor combines the receiver location with the tag ID to determine the location of the object associated with the tag. However, these systems have several limitations. Location data maintained by the central processor has limited accessibility from locations other than the central processor. All location data is maintained by the central processor. Any location monitoring devices that send location data to the central processor must be specifically designed to work with the central processor, and must be like all the other location monitoring devices connected to the central processor. All of the location data must be sent to the central processor and anytime communication with the central processor is lost the location data collected by the disconnected location monitoring devices is inaccessible. The central processor receives location updates but does not forward location data to other monitoring systems.

SUMMARY OF THE INVENTION

[0004] An illustrated embodiment of the present invention includes a central location database that can be accessed from any computer with network access to the central server through Intranet or Internet using a standard web browser interface. The web browser interface is illustratively created using a Microsoft technology called Active Server Pages and the programming language VBScript. Active Server Pages allow the creation of dynamic web pages which are tailored according to the requests of the client queries. The dynamic server pages are interpreted by the web browser to provide virtually complete access to the location databases and other databases maintained on the central server. Any computer with communications network access to the central server and supporting a web browser interface can access the location data and other data stored on the central server.

[0005] The illustrated embodiment of the present invention allows the tracking and locating of objects over a large area by combining the object transmissions received over multiple sub-areas which are monitored by autonomous monitoring systems interconnected through a communications network. Each location monitoring system sends the location updates to the central server over the communications network. The central server can maintain location data for a large area by receiving location updates over several sub-areas which each have a location monitoring system tracking object tags in their particular sub-area. The area and sub-areas could be a building and its floors, a campus and its buildings, or several campuses and the floors of each of the buildings on each of the campuses. The sub-area monitoring systems only have to be able to track the same tags and have access to the central server over a communications network for a client connected to the central server to obtain location information on an object anywhere in the awareness area.

[0006] The illustrated embodiment of the present invention supports locating and tracking over the entire area using both dependent locating and tracking system, locating and tracking systems which depend upon the central database to store location data and to respond to database queries, and independent locating and tracking systems, locating and tracking systems which forward location data to the central server as well as maintaining local sub-area location databases. Each of the sub-area monitoring systems can either send all data to the central server for recording, a dependent monitoring system, or have a local database for objects assigned to the local sub-area and also send location updates to the central server, an independent monitoring system. If either monitoring system loses communication with the central server it will store location updates to transmit when communication is restored. An independent monitoring system will continue to support local location queries for the objects assigned to its sub-area when communication is lost with the central server. The central server can also pass location updates and messages back to the independent monitoring systems. If an object assigned to sub-area A is in another sub-area monitored by the central server then location updates can be recorded at the central server and forwarded to sub-area A to keep the local database updated even when the objects are outside sub-area A. The independent monitoring system can also assign new tags to the sub-area and receive updates from anywhere monitored by the central server. However, when communication with the central server is lost only objects within the sub-area can be tracked.

[0007] Additional advantages and features of the invention are set forth in the description that follows, and will become apparent to those skilled in the art upon reviewing the drawings in connection with the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] **FIG. 1** is a block diagram of the layout of the personnel and asset tracking system.

[0009] **FIG. 2** shows the interconnection of the components of a dependent monitoring system.

[0010] **FIG. 3** shows the interconnection of the components of a receiver node.

[0011] **FIG. 4** is a detailed design of the receiver node audio annunciator.

[0012] **FIG. 5** is a detailed design of the receiver node auxiliary I/O connector.

[0013] **FIG. 6** shows the procedure used by a location processor for processing a presence message.

[0014] **FIG. 7** shows the procedure used by a location processor for processing an entry message.

[0015] **FIG. 8** shows the procedure used by a location processor for processing an exit message.

[0016] **FIG. 9** shows the procedure used by a location processor for processing a presence message when the location processor has exit timer capability.

[0017] **FIG. 10** shows the procedure used by a location processor when an exit timer expires.

[0018] **FIG. 11** shows the procedure used by a location processor for processing an exit message or the expiration of an exit timer when the location processor has an extended exit timer.

[0019] **FIG. 12** shows a block diagram of the central server web browser interface and the associated application programs and databases on the central server with connection to clients.

[0020] **FIG. 13** is a flowchart of the rules processing by the Awareness Engine Monitor when a location update message is received.

DETAILED DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1** illustrates the interconnection of the primary components of the personnel and asset tracking system. The heart of the system is the central server **10** which maintains the awareness area databases **11** for the system over the entire area in which awareness of personnel and assets is to be monitored, the awareness area **2**. The central server **10** receives location and status updates from at least one monitoring system through a communications network **12**. Each monitoring system monitors personnel and assets throughout a sub-area of the awareness area, a sub-awareness area. **FIG. 1** shows an independent monitoring system **25** monitoring a sub-awareness area **4** and a dependent monitoring system **15** monitoring another sub-awareness area **6**. Both the dependent monitoring system **15** and the independent monitoring system **25** send location updates to the central server **10** over the network **12**. The dependent monitoring system **15** does not maintain a local database, and thus depends on the central server **10** to handle location queries from clients **40**. The independent monitoring system **25** maintains a local sub-awareness area **4** location database on the master station **24**, and thus can support local queries for objects assigned to it independent of the central server **10**. The independent monitoring system **25** receives signals transmitted by a personnel badge **50** worn by a person **51** and an asset tag **52** attached to an asset **55**. The dependent monitoring system **15** receives signals transmitted by another personnel badge **50** worn by a person **53** and another asset tag **52** attached to an asset **57**. An awareness area **2** and sub-awareness areas **4**, **6** could be a building and its floors or a campus and its buildings. Each entity to be monitored in the awareness area **2** wears a personnel badge **50** or an asset tag **52** which transmits a unique object ID signal.

[0022] Access to the awareness area databases **11** maintained at the central server **10** can be gained from a client **40** or an administrative station **44** through the network **12**. Client **40** can be connected to the network **12** locally (e.g. Intranet) or remotely (e.g. Internet). Independent monitoring system **25** can also access the awareness area databases **11** maintained on the central server **10** through the hospital network **12**.

[0023] There are two types of sub-awareness area monitoring systems. A dependent monitoring system **15** is connected to the hospital network **12** through a router **14** as shown in **FIG. 2**. A dependent monitoring system **15** does not maintain sub-awareness area databases or support sub-awareness area queries but rather forwards all information to the central server **10**. A dependent monitoring system **15** is comprised of a router **14**, at least one hub **16** and a plurality of nodes **18**. Each node **18** continuously monitors a particular area in the sub-awareness area for personnel badge **50** and asset tag **52** transmissions. Each node **18** communicates with and sends location messages to a hub **16**. The hub **16** communicates with and sends location messages to the router **14**. The router **14** communicates with and sends location messages to the central server **10** over the hospital network **12**.

[0024] The second type of sub-awareness area monitoring system is an independent monitoring system **25** as disclosed in U.S. Pat. No. 5,561,412 which is hereby incorporated by reference. An independent monitoring system **25** has a set of personnel badges **50** assigned for which it maintains a local database on its master station **24** which also supports local queries and status messages. The master station **24** communicates with the central server **10** over the hospital network **12**.

[0025] In either type of monitoring system the process is triggered by the reception of a personnel badge **50** or asset tag **52** transmission at a receiver node **18**. The receiver node **18** generates a presence or entry message which is sent to a downstream location processor. A detailed diagram of the receiver node **18** is shown in **FIG. 3**. The receiver **18** includes a microprocessor **30**. The receiver **18** of a dependent monitoring system **15** receives power and data inputs **34** from the hub **16**. The dip switches **36** are used to configure the receiver **18** for use with either a dependent monitoring system **15** or an independent monitoring system **25**. The multiple infrared detectors **32** receive the transmissions of personnel badges **50** and asset tags **52** and relay them to the microprocessor **30**, which processes the badge transmissions and can forward a location message to the next upstream location processor over the data lines **34**. The 48 bit silicon ID is set to a unique address to identify the node **18**. The node **18** also has a LED **60**, an audio annunciator **62** and a auxiliary I/O connector **64**.

[0026] A detailed drawing of the audio annunciator **62** is shown in **FIG. 4**. If the audio annunciator **62** of the node **18** is selected then a control signal will be sent by the microprocessor **30** at the connection **412** through the resistor **414**. A resistor **416** ties the base of the transistor **418** to the voltage source. The control signal from the transistor **418** passes through resistors **422** and **420** to activate the audio switches **424**, **430** and the audio line transformer **400**. The

audio signal is input from an audio amplifier over connector **408**. The audio input is processed simultaneously by two parallel and totally isolated audio switches. The audio signal passes across a pair of optically isolated FET switches **424, 430** which transmit an optical signal to the photo-transistors **426, 432** which are each in parallel with a noise suppression diode **428, 434**. The output audio signal is input to the audio line transformer **400** through connector **402**. The output of the audio line transformer **400** is sent through connectors **402** and **406** to speaker **410**. Switch **404** controls the volume of the signal sent to speaker **406**.

[**0027**] A detailed diagram of the auxiliary I/O connector **64** of the node **18** is shown in **FIG. 5**. The auxiliary I/O connector **64** is connected to the microprocessor **30** through the lines **500-512**. Each line to the microprocessor **30** is protected by a current limiting resistor **517-529** and a zener diode clamp **540-553** to protect from reverse or over-voltages. Each line is also connected to a input/output line at connector **560**. These auxilary lines could be used for inputs or outputs. Examples of inputs are monitoring room temperatures or the presence of persons without a personnel badge or for outputs. Examples of outputs are thermostat controls, light controls or buzzers.

[**0028**] Inter-Location Messages

[**0029**] Both a dependent monitoring system **15** and an independent monitoring system **25** is comprised of an infrastructure with multiple location processor levels. The most upstream location processors are the nodes **18** which receive the badge/tag transmissions and pass them downstream and generate the initial location messages. These location messages are passed downstream to intermediate location processors which pass the location messages to the downstream location processors which are either a router **14** or a master station **24** that passes the location message to the central server **10**. A location message begins with the reception of an object ID from a personnel badge **50** or asset tag **52** transmission and ultimately ends with the updating of a database **11** such that the best location data is available for all objects being tracked. A location processor can function in either a pass-through or a buffered mode. In pass-through mode any location message received by the location processor is passed to the next location processor in the stream leading to the central server **10**. In buffered mode the location processor maintains a cache with a stack for each object ID it is currently tracking and only passes along changes in the status of a particular object ID. The inter-location messages in buffered mode can be either presence messages, entry messages or exit messages, while the inter-location messages in pass-through mode are presence messages. Each of these messages is for a particular personnel badge **50** or asset tag **52** object ID at a particular awareness area location. Entry and exit messages also have a time stamp associated with them identifying the time the event occurred.

[**0030**] A presence message simply indicates that a particular object 1D is present at a particular awareness area location. A presence message is generated at a node **18** when it receives a personnel badge **50** or asset tag **52** transmission or is received at a downstream location processor from an upstream pass-through location processor. The processing of a presence message by the first buffered location processor is shown in **FIG. 6**. The process is initiated by the reception of a tag transmission at a node **18** or the reception of a presence message from an upstream location processor **110**. The location processor receiving the presence message checks if it is currently tracking this object ID **111**. If the object ID is currently being tracked, the location processor checks if the top entry in the stack for this object ID already shows the same location as the presence message **112**. If the top entry of the stack already contains this object ID and receiver pair then there is no change in the object's location and no further processing is required. If its cache does not contain this object ID or it shows a different location then there has been a location change for this object. The location processor adds the object ID and receiver pair to the top of the stack for the object ID in its cache **114**, time stamps the message **116**, and sends an entry message to the next downstream location processor **118**.

[**0031**] An entry message indicates the transition of an object ID from not being detected at a particular location to being detected at that particular location. An entry message is created by an upstream location processor and sent downstream. The processing of an entry message is shown in **FIG. 7**. This process is initiated by the receipt of an entry message **120**. The location processor receiving the entry message checks if it is currently tracking this object ID **121**. If the object ID is currently being tracked, the location processor checks if the top entry in the stack for this object ID already shows the same location as the entry message **122**. If the top entry of the stack already contains this object ID and receiver pair then there is no change in the object=s location and no further processing is required. If its cache does not contain this object ID or it shows a different location then there has been a location change for this object. The location processor adds the object ID and receiver pair to the top of the stack for the object ID in its cache **124**, time stamps the message **126**, and sends an entry message to the next downstream location processor **128**.

[**0032**] An exit message indicates the transition of an object ID from being detected at a particular location to not being detected at that particular location. An exit message is created by an upstream location processor and sent downstream. The processing of an exit message is shown in **FIG. 8**. This process is initiated by the receipt of an exit message **130**. The location processor receiving the exit message checks if it is currently tracking this object ID **131**. If the object ID is currently being tracked, the location processor checks if the top entry in the stack for this object ID already shows the same location as the presence message **112**. If top entry does not contain this object ID and receiver pair then the object ID is not associated with the location and no further processing is required. If the top entry of the stack contains this object ID and receiver pair then the object ID and receiver pair is removed from the cache **134** and the exit message is sent to the next downstream location processor **136**.

[**0033**] Buffered location processors can maintain up to two timers related to exit processing. The first, an exit timer is kept at the most upstream buffered location processor which could be a node **18** receiving object ID transmissions from a personnel badge **50** or asset tag **52**, or a downstream location processor receiving presence messages from an upstream pass-through location processor. The exit timer is

used to generate an exit message if presence messages are not received for a particular object over a predetermined time interval.

[0034] The initialization of an exit timer for a particular object ID is shown in **FIG. 9**. The process is initiated by the receipt of a presence message **140**. The location processor receiving the presence message checks if its cache already contains this object ID and receiver pair **142**. If its cache already contains this object ID and receiver pair then the exit timer is reset **149** and no further processing is required. If the cache does not contain this object ID and receiver pair then an entry condition has taken place for this object. The location processor adds the object ID and receiver pair to its cache **144**, sets the exit timer for this object depending on whether it is an personnel badge **50** or asset tag **52** transmission **146**, time stamps the object ID and receiver pair **147**, and sends an entry message to the next downstream location processor **148**.

[0035] The process that occurs when the exit timer expires for a particular object ID and location pair is shown in **FIG. 10**. This process is initiated by the expiration of the exit timer **150** which indicates that no presence messages have been received by the location processor since the exit timer was last set, and therefore the object is assumed to have left the location it was last associated with by this location processor. When the exit timer expires the object ID and receiver pair is removed from the cache **152**. The location processor then checks if the object ID/location pair associated with this exit timer is at the top of its cache **154**. If this pair is at the top of the stack an exit message is sent downstream **156**. The location processor then checks if there are remaining entries in the stack for this object ID **158**. If there are remaining entries, an entry message is sent downstream for the new location at the top of the cache for this object ID **159**.

[0036] The second timer associated with exit message processing is an extended exit timer. An extended exit timer further delays the sending of an exit message downstream as shown in **FIG. 11**. Extended exit timer processing is initiated by the receipt of an exit message **160** or the expiration of an exit timer **162**, either of which starts the extended exit timer **164** if the location processor is equipped for this processing. The location processor will then check for the expiration of the extended exit timer **166**. If the extended exit timer expires before the receipt of an entry message for the particular object ID then an exit message is sent downstream with the time stamp of the original exit message **174** and no further processing is required. If an entry message is received for the particular object ID before the extended exit timer expires **168** then the location processor checks if the location of the entry message is the same as the object ID/location pair associated with the extended exit timer **170**. If the location is the same then the object has not changed location and the extended exit timer is canceled **172** and no further processing is required. If the location is different then the object has changed location; the extended exit timer is canceled **176**, an exit message is sent for the location associated with the extended exit timer with the time stamp of the entry message **178**, and an entry message is sent for the new location with the time stamp of the entry message **179**.

[0037] A downstream location processor can request an upstream location processor to send the contents of its cache showing the object IDs that the upstream location processor is tracking. The response message consists of a list of object IDs and their associated locations.

[0038] Action Message Processing

[0039] Each personnel badge **50** is equipped with an action button or switch which is used to send an alert signal. A unique system response can be defined for the reception of an alert signal from each personnel badge **50** tracked by the system. The primary response is maintained at the central server **10**, and for an independent monitoring system **25** a secondary response can be maintained at the master station **24**. The secondary response is initiated if either communication is lost between the central server **10** and the master station **24** or if no primary response has been programmed at the central server **10**.

[0040] The object IDs of all personnel badges **50** and asset tags **52** have a zero for the most significant bit. When the action button or switch is triggered then the most significant bit is set to "1" which constitutes an alert signal. When a location processor receives an alert signal it makes an audible or visual response if equipped with a means for audible or visual response.

[0041] A sub-awareness area monitoring system passes the alert signal to the central server **10**. The central server **10** records the time that the alert signal was sent and looks up the programmed response for the particular object ID. The programmed response can include instructions to send a notification message to one or more monitoring clients **40**, or to direct an audio message to the audio annunciator of one or more nodes **18**, or to send a message to a pocket pager. The central server **10** sends notification messages to all monitoring clients **40**, nodes **18** and pocket pagers as instructed by the pre-programmed response. Each monitoring client **40** that receives the notification message sounds an audible tone indicating that a notification message has been received and a pop-up window is displayed on the monitoring client **40** indicating the personnel badge **50** that has sent the alert signal and the location from where the alert signal was sent. The person at the monitoring client **40** acknowledges the alert signal by closing the pop-up window, which sends an alert acknowledgment message back to the central server **10** which records the alert acknowledgment time. An independent monitoring system **25** may also have a secondary response stored on the master station which is initiated in addition to the central station **10** response. When the secondary alert process has been acknowledged the master station **24** sends an alert acknowledgment message back to the central server **10** which records the alert acknowledgment time.

[0042] Central Server and Client Communication

[0043] A top-level diagram of the communications between the central server **10** and potential clients **14**, **24**, **34** over the network **12** is shown in **FIG. 12**. There are three types of clients that are in contact with the central server **10**. The first is a dependent monitoring system router **14**. The router **14** is in communication with the central server **10** sending location messages for the sub-awareness area that the dependent monitoring system **15** is monitoring. The second type of client is an independent monitoring system master station **24**. The master station **24** is in two-way communication with the central server **10** sending location

messages for the sub-awareness area that the independent monitoring system **25** is monitoring, and primarily receiving location updates for personnel badges **50** assigned to the independent monitoring system **25** which are received from outside the sub-awareness area that the independent monitoring system **25** is monitoring. The third type of client is a network client **40**. Network clients **40** primarily query the central server **10** for location- and tracking data to create screen displays or reports, they do not provide location updates but they can update other data on the central server **10**.

[**0044**] The interface between the central server **10** and the network client **40** is a Web browser interface commonly used on the Internet. The interface between the central server **10** and the dependent monitoring system router **14** or the independent monitoring system master station **24** can be web browser based or through other network communication methods. The web server **210** is developed with Internet Information Server (IIS) software, developed by Microsoft, on the central server **10** provides the necessary functionality to host a Web site that can intercept and interpret information requests or updates, call the service providers to make the necessary database queries or updates, and create a a dynamic Web page responsive to the information request or update. The web server **210** can service multiple clients over an Internet or Intranet from a single central server **10**. The service providers for the web server **210** are applications that can update, query and maintain databases containing information of interest to the clients.

[**0045**] The primary location and tracking databases on the central server **10** are as follows. The Location Update Cache **290** contains the current location of all personnel badges **50** and asset tags **52**, ordered by location. The Location/Tag ID Cache **292** contains the current location of all personnel badges **50** and asset tags **52**, ordered by Tag ID. Having the current location of all personnel badges **50** and asset tags **52** ordered by both location and Tag ID allows increased system performance when responding to database queries. The Rules Cache **296** contains rules defined for objects and locations such that when a rule is violated a message is sent to interested client **24**, **34**. The Registered Interests Cache **294** contains a cross-reference between clients **24**, **34** and interests for which the client **24**, **34** is registered. The Database Transaction Queue **298** contains all of the incoming and processed transactions from networked clients. The SQL Database **300** contains a record of all database change events that have occurred and their times.

[**0046**] The Location Update application **212** receives location updates from dependent monitoring systems **15** and independent monitoring systems **25**. The location updates can be in the form of entry messages or exit messages if the monitoring system is buffered or in the form of presence messages if the monitoring system is pass-through. The Location Update application **212** updates the object ID/location pair in both the Location Update Cache **290** and the Location/Tag ID Cache **292**, and also enqueues the transaction in the Transaction Queue **298**.

[**0047**] The Interests application **214** receives interests from clients that a user would like to add to or delete from the Registered Interests Cache **294**. Interests are events that a client application wants to be notified of when the event occurs. Examples of interests are alarm events and personnel badge **50** assignment changes. The Interests application **214** records the event and client that wants to be notified of the event in the Interests Cache **294** and also enqueues the transaction in the Transaction Queue **298**.

[**0048**] The Tag Association application **218** manages the association and disassociation of personnel badges **50** and asset tags **52** to people and assets, respectively. The Tag Association application **218** receives instructions from a client and makes the appropriate updates to the Location/Tag ID Cache **292** and enqueues the transaction to the Transaction Queue **298**.

[**0049**] The Non-Interactive Database application **220** handles all database transactions that do not require a user response. The Direct Database Access application **222** handles all transactions that require access to the SQL Database **300**.

[**0050**] The Awareness Engine Monitor **230** constantly watches the caches for the occurrence of alarm and interest events stored in the Interests Cache **294** or violations of the rules stored in the Rules Cache **296**. When an interest event occurs or a rule has been violated the Awareness Engine Monitor **230** sends an appropriate notification to the clients that have registered for that event. A flowchart of the rules processing performed by the Awareness Engine Monitor **230** is shown in **FIG. 13**. The process is initiated by the receipt of a location message by the web server **210** of the central server **10**, as shown in step **310**. When the location update is passed to the Awareness Engine Monitor **230**, the following processes are performed. First, the location entry is updated in the Location/Tag ID Cache **292** to indicate a new object ID at this location, as shown in step **320**. The Awareness Engine Monitor **230** then checks if any rules concern this location **322**. Second, the object ID entry in the Location Update Cache **290** is updated to indicate that the object ID is located at the new location, as shown in step **330**. The Awareness Engine Monitor **230** then checks if any rules concern this object ID **332**. Third, the Awareness Engine Monitor **230** checks if there are any global rules, those that do not concern a particular object or location ID, triggered by this update **340**. The Awareness Engine Monitor **230** then checks whether any of the rules found in steps **322**, **332** and **340** are violated, as shown in step **350**. If any rule was violated the Awareness Engine Monitor **230** checks if the Registered Interests Cache **294** has a client to be notified of the rule violation **352**. A message is sent by the central server to any registered client indicating the rule violation that occurred **354**. The client can then perform the response it is programmed to perform when the notification is received **356**.

[**0051**] The Subscription Service application **216** is also used for event notification and alarms. The Subscription Service application **216** sends the notification message to the client that has subscribed to be notified of a particular event. An example is an independent monitoring systems **25** that wants to be informed when a personnel badge **50** assigned to the sub-awareness area being monitored by the independent monitoring system **25** is detected outside of that particular sub-awareness area. In this instance, the Subscription Service application **216** will be initiated when an assigned badge **50** of the independent monitoring system **25** is detected outside its sub-awareness area and the Subscription Service application **216** will send a location message to the

independent monitoring system **25** to be used to update the local sub-awareness area database being maintained by the master station **24**.

[**0052**] The Awareness Engine Queue Processor **224** processes all transactions in the enqueue of the Transaction Queue **298** to update the SQL Database **300**. When a request is received by the Web Server **210** it is handed off to the appropriate service provider application. If the request involves a database update, the appropriate update information is placed in Transaction Queue **298**. Once a transaction is successfully processed by the Awareness Engine Queue Processor **224** it is moved to the dequeue of the Transaction Queue **298**. If a transaction is not successfully processed by the Awareness Engine Queue Processor **224** it is moved to a separate part of the dequeue for failed transactions. From here an Administrative Client **44** can review the transaction, make any necessary changes and requeue the transaction for processing by the Awareness Engine Queue Processor **224**. An Administrative Client **44** also periodically cleans up dequeued transactions.

[**0053**] The data flow from the tag transmission to the appropriate database updates at the central server **10** is as follows. A personnel badge **50** or asset tag **52** transmission is detected by a receiver node **18** and the receiver node **18** generates a location message which it sends downstream. If the receiver node **18** is part of a dependent monitoring system **15** the location message is sent to the router **14** which sends the location message across the network **12** to the central server **10** without any intermediate storage. If the receiver is part of an independent monitoring system **25** it is stored at the master station **24** and the master station **24** also sends the location message across the network **12** to the central server **10**. The web browser **210** on the central server **10** receives the location message. The web browser **210** passes the location message to the Location Update program which updates the Location Update cache **290** and the Location/Tag ID Cache **294** and checks the Rules Cache **296** for any actions that are to be performed based upon the update. A transaction is also sent to the Transaction Queue **298** which will be processed by the Transaction Queue Processor **224** to make a historical record of the update on the SQL Database **300**.

[**0054**] Client Interfaces

[**0055**] The master station **24** of an independent monitoring system **25** can be a client of the central server **10**. The nodes **18** of the independent monitoring system **25** receive transmissions from personnel badges **50** and asset tags **52** in the sub-awareness area covered by the independent monitoring system **25**. These transmissions are converted into location messages which are forwarded to the master station **24** which updates the local sub-awareness area database and transmits the location update to the web browser **210** on the central server **10** which collaborates with the appropriate programs to update the Location Update cache **290**, the Location/Tag ID Cache **292** and the SQL Database **300**.

[**0056**] The independent monitoring system **25** has several important advantages due to its connection to the central server **10**. The first advantage is that the independent monitoring system **25** can track the personnel badges **50** and asset tags **52** assigned to the independent monitoring system **25** even when they are outside of the sub-awareness area monitored by the independent monitoring system **25**, as long as they are within the awareness area. All of the objects that an independent monitoring system **25** wants assigned are listed in the Interests Database **294** with the identity of the independent monitoring system to be notified. When an object is within the awareness area but outside the independent monitoring system's **25** sub-awareness area, the central server **10** will receive a location message for the object from another client. When this location message is detected by the Awareness Engine Monitor **230** it will recognize the interest in the Interest Database **294** and send a location message for the object to the independent monitoring system **25** using the Subscription Service application **216**.

[**0057**] This same functionality can be used by an independent monitoring system **25** to add objects that it wants to track in its local sub-awareness area database. A message would be sent from the master station **24** of the independent monitoring system **25** to the Web Server **210** of the central server **10** to register an interest for the new object. The Interests application **214** would record the interest in the Interests Database **294** and the Awareness Engine Monitor **230** would inform the independent monitoring system **25** of any location messages received for the associated object badge/tag outside the independent monitoring system's **25** sub-awareness area.

[**0058**] The connection to the central server **10** also allows the independent monitoring system **25** to resolve the identity of personnel badges **50** and asset tags **52** which are not assigned to the sub-awareness area when they are detected within the sub-awareness area. The master station **24** of the independent monitoring system **25** will send a location message for an object not assigned to its sub-awareness area and also store the location message in a visitor cache. If the master station **24** does not know the identity of the object associated with the location message it will send a query to the Internet Information Server **210** of the central server **10**. The Direct Database Access program **222** in the central server **10** will query the SQL Database **300** and send a response containing the identity of the object for use in the local sub-awareness area database of the independent monitoring system **25**.

[**0059**] Connection to the central server **10** also allows a user at the master station **24** of the independent monitoring system **25** to perform location searches for any locateable entity in the awareness area known to the central server **10** or other functions that can be performed from a client **40**.

[**0060**] A client **40** is used to access information maintained by the central server **10**. A client **40** has a web browser interface through which a user communicates with the Web Server **210** of the central server **10** to query or update information maintained in the central server **10** databases. The two primary location viewing applications of the client **40** are the Personnel View and Asset View functions. The client **40** can be a computer assigned to an individual that contains the Personnel View and Asset View software packages and has access to the central server **10** via an Internet or Intranet connection.

[**0061**] Personnel View allows a user to locate personnel associated with personnel badges **50**, to assign and deassign personnel to personnel badges for tracking in the awareness area, to maintain and update personnel information stored by the central server **10**, and to perform administrative functions. When a user wishes to use the Personnel View

function they must first login to the system to indicate the user's identity and to prevent unauthorized access.

[0062] A personnel search can be performed from a standard search screen or the user can set-up a list of common searches they wish to perform and simply select one of these pre-defined searches. Personnel searches can be run based on first name, last name, department, skill and location with filter options of begins with, contains, or equals. Fields maintained in the Personnel Database on the central server **10** include name, department, skill, time since badge last seen, location where badge last seen, nearest phone number to location where badge last seen, name and phone number of person taking calls for this person, and mobile phone number for person. When the information is displayed for the located person or persons several fields may be highlighted showing a link to additional information about the hyperlinked item. For instance, location, department, organization or skill fields could be highlighted to indicate that an explanation of the contents or codes used for each of these fields is available which the user can access by selecting the highlighted field. An edit option is also available to the user to edit any information stored in the personnel databases on the central server **10** for the user login entered or for those personnel that have authorized updates by the user login entered.

[0063] A user can also log onto Personnel View and enter status information. An out to lunch or gone home option will set the location of the badge associated with the logged on user to "Out to Lunch" or "Gone Home" respectively and provide an expected return time. The expected return time can be either a default time or default length of time from when the message was activated or can be over-ridden by a time entered by the user. A search that includes that user will return the location message and expected return time until the expected return time is passed. After the expected return time passes the normal location message will be returned for the user. A do not disturb option, if selected by the user, will display "Do Not Disturb" along with the location information for any search performed that returns the user=s location. This message will continue to be displayed until disabled by the user.

[0064] Asset View allows a user to locate assets associated with an asset tag **52**, to assign and deassign assets to asset tags for tracking in the awareness area. When a user wishes to use the Asset View function they must first login to the system to indicate the user=s identity and to prevent unauthorized access.

[0065] An asset search can be performed from a standard search screen or the user can set-up a list of common asset searches they wish to perform and simply select one of these pre-defined searches. Asset searches can be run based on standard asset description, add-on description, asset ID, asset category, location, or vendor with filter options of begins with, contains, or equals. Fields maintained in the Asset Database on the central server **10** include asset name, asset serial number, time since tag last seen, location where tag last seen, asset owner's name and phone number. When the information is displayed for the located asset several fields may be highlighted showing a link to additional information about the hyperlinked item.

[0066] A client **40** can also be equipped to support report generation and report design. The report design function is internal to the client **40** and allows the user to customize the content of a report and the arrangement of data fields. The report generator allows the user to select a predefined report which was designed with the report designer. When the user runs the report the report generator uses a web browser interface to communicate over a network connection to the web browser **210** of the central server **10**. The necessary data from the central server databases is retrieved and sent back to the client **40**. The report client formats the returned data according to the report design. The user can then display, print or save the report.

[0067] It will be understood that various modifications can be made to the system disclosed in this application without changing the scope of the invention as set forth in the claims attached hereto.

1. In a locating and tracking system, a method for processing location messages, comprising the steps of:

receiving a location message,

determining whether an entry condition has occurred,

starting a timer if an entry condition has occurred, and

generating an exit message if the timer expires after a predetermined time during which no location messages are received.

2. In a locating and tracking system, a method for processing action messages, comprising the steps of:

receiving an alert signal,

determining whether a first response to the alert signal is available,

initiating the first response if the first response is available,

determining whether a second response to the alert signal is available, and

initiating the second response if the second response is available.

3. The method of claim 2, wherein the alert signal is received from a tag.

4. The method of claim 2, wherein the first response is maintained by a first computer and the second response is maintained by a second computer.

5. The method of claim 2, wherein the step of initiating the second response is performed only if the first response is not initiated.

6. The method of claim 2, wherein the first response and the second response are one of an audible, visual, and electronic response.

7. The method of claim 6, further comprising the step of sending one of the first response and the second response to a pager.

8. The method of claim 6, further comprising the step of sending one of the first response and the second response to an audio annunciator.

9. The method of claim 6, further comprising the step of sending one of the first response and the second response to a client.

10. The method of claim 2, further comprising the step of storing the alert signal at a central server.

11. The method of claim 2, further comprising the step of storing the time that the alert signal was received.

12. A method for processing a location message in a system for locating and tracking objects, the method comprising the steps of:

receiving a location message,

evaluating the location message to determine whether an event has occurred,

determining whether a notification is needed based on the results of the evaluating step, and

notifying a client if necessary based on the results of the determining step.

13. The method of claim 12, wherein the evaluating step includes the step of comparing a current location to a prior location.

14. The method of claim 12, wherein the evaluating step includes the step of determining whether a rule applies based on the location message.

15. The method of claim 12, wherein the evaluating step includes the steps of determining whether the location message invokes any rules, and determining whether the location message violates any rules.

16. The method of claim 12, wherein the notifying step includes the step of determining whether the client is registered to be notified of the event.

17. The method of claim 12, wherein the location message includes information relating to an object at a location.

18. The method of claim 12, wherein the notifying step includes the step of determining which client to notify of the event.

19. The method of claim 12, further comprising the step of verifying that the client wants to be notified of the occurrence of the event prior to notifying the client.

20. The method of claim 12, wherein the event includes a change in location of a tag.

21. The method of claim 12, wherein the event includes a change in status of a tag.

22. The method of claim 12, wherein the event includes a tag being present at a location.

23. The method of claim 12, wherein the event includes a tag exiting from a location.

24. The method of claim 12, wherein the event includes a tag entering a location.

25. In a system for locating and tracking objects, a computer program product operable to process a location message, comprising:

means for receiving a location message,

means for evaluating the location message to determine whether an event has occurred, and

means for notifying a client of the occurrence of an event if an event has occurred.

26. In a locating and tracking system, a method for processing location messages, the method comprising the steps of:

receiving a location update,

storing the location update in a memory,

processing the location update to determine whether a rule applies,

generating a notification pursuant to an applicable rule, and

sending the notification to a client.

27. The method of claim 26, wherein the location update includes tag information for a location.

28. The method of claim 26, wherein the location update includes location information for a tag.

29. The method of claim 26, wherein the rule is associated with a tag.

30. The method of claim 26, wherein the rule is associated with a location.

31. The method of claim 26, wherein the rule is associated with an asset assigned to a tag.

32. The method of claim 26, wherein the rule is associated with a person assigned to a tag.

33. The method of claim 26, wherein the rule is defined by a user.

34. The method of claim 26, wherein the rule is associated with an event.

35. The method of claim 26, wherein the event includes a tag changing location.

36. The method of claim 26, wherein the event includes a tag entering a location.

37. The method of claim 26, wherein the event includes a tag exiting a location.

38. The method of claim 26, wherein the event includes a change in status of a tag.

39. In a locating and tracking system, a method for processing status updates, the method comprising the steps of:

receiving a status update,

storing the status update in a memory,

processing the status update to determine whether a rule applies,

generating a notification pursuant to an applicable rule, and

sending the notification to a client.

40. The method of claim 39, wherein the status update relates to a tag.

41. The method of claim 39, wherein the status update relates to a location.

42. The method of claim 39, wherein the status update relates to an asset assigned to the tag.

43. The method of claim 39, wherein the status update relates to a person assigned to the tag.

44. The method of claim 39, wherein the rule is defined by a user.

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