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(54) **Title:** WIRELESS TRACKING SYSTEM AND METHOD WITH MULTIPATH ERROR MITIGATION

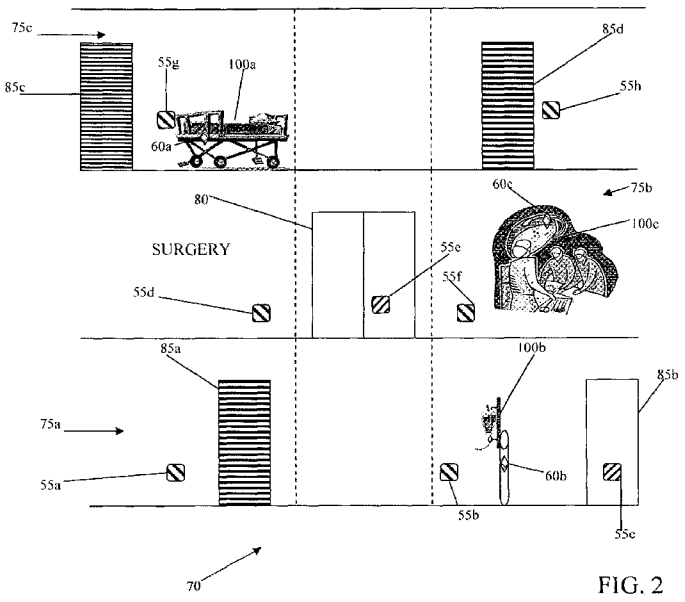

FIG. 2

(57) **Abstract:** A system (50) and method (300) for providing multipath error mitigation for real-time wireless tracking of an object (100) is disclosed herein. A plurality of sensor readings are obtained from a tag (60) attached to an object (100) within an indoor facility (70). A plurality of reading sets are generated and sorted by zones. A zone with the highest average reading is preferably selected and the location of the object (100) is calculated based on the selected zone readings. In this manner, faulty position readings are eliminated from the location calculation thereby allowing for more accurate tracking of the object (100) within the indoor facility (70).

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Title

Wireless Tracking System And Method With Multipath Error Mitigation

(Docket Number AWP003-PCT)

Technical Field

The present invention is related to wireless tracking systems and methods. More specifically, the present invention relates to a system and method for mitigating multipath errors associated with the wireless tracking of objects.

Background Art

The ability to quickly determine the location of objects located within a facility is becoming a necessity of life. To the uninformed observer, the placement of transponders, also known as tags, on numerous non-stationary objects whether in an office or home would appear to be an unnecessary use of resources. However, the uninformed observer fails to appreciate the complexity of modern life and the desire for efficiency, whether at the office or home.

For example, in a typical hospital there are numerous shifts of employees utilizing the same equipment. When a new shift arrives the ability to quickly locate medical equipment not only results in a more efficient use of resources, but also can result in averting a medical emergency. Thus, the tracking of medical equipment in a hospital is becoming a standard practice.

The tracking of objects in other facilities is rapidly becoming a means of achieving greater efficiency. A typical radio frequency identification system includes at least multiple tagged objects, each of which transmits a signal, multiple receivers for receiving the transmissions from the tagged objects, and a processing means for analyzing the transmissions to determine the locations of the tagged objects within a predetermined environment. One exemplary method triangulates the strongest received signals to determine the location of a tagged object. This method is based on the assumption that the receivers with the strongest received signals are the ones located closest to the tagged object. However, such an assumption is sometimes erroneous due

to common environmental obstacles. Multipath effects can result in a further located receiver having a stronger signal from a tagged object than a more proximate receiver to the tagged object, which result in a mistaken location determination.

Tekinay, U.S. Patent Number 6259894 for a *Method For Improved Line-Of-Sight Signal Detection Using RF Model Parameters*, discloses a method for reducing time-shift due to multipathing for a RF signal in an RF environment.

Close, U.S. Patent Number 3869673 for a *Method And Apparatus For Measuring Multipath Distortion*, discloses a method for indicating multipath distortion in a received signal.

Lennen, U.S. Patent Number 5402450 for a *Signal Timing Synchronizer*, discloses a method and apparatus for reducing the effects of multipath induced distortions on the accuracy of detecting the time of arrival of a received signal.

Fortune et al., U.S. Patent Number 5450615 for a *Prediction Of Indoor Electromagnetic Wave Propagation For Wireless Indoor Systems*, discloses techniques for predicting RF propagation within a structure.

The prior art has yet to resolve mistaken location calculations based on multipath effects.

Summary Of The Invention

One aspect of the present invention is a method for determining a real-time location of an object within an indoor facility. The method begins with obtaining a plurality of sensor readings from a transponder attached to the object. Next, a reading set is generated from the plurality of sensor readings. The reading set is then sorted by a plurality of physical regions. Then, a first physical region is selected from the plurality of physical regions. The first physical region is composed of a first plurality of sensor readings that have the highest average signal strength. Next, the first plurality of sensor readings is sorted into a second plurality of sensor readings. Each of the second plurality of sensor readings corresponds to sensor located in a zone within the first physical region. A selected zone having the highest average reading is then

selected. Next, a real-time location of the object is calculated using only the second plurality of sensor readings that correspond to the selected zone.

Each sensor reading preferably comprises a signal strength, link quality, time and identification of the transponder. The method may further comprise displaying the real-time location of the object on a graphical user interface. The method may also include comparing the calculated real-time location of the object to a previously calculated location for the object. The method may include monitoring the motion state of the object to confirm movement of the object from the previously calculated location to the real-time location. In a preferred embodiment, the indoor facility is a hospital, with each of the plurality of physical regions being a floor of the hospital, and the selected zone being a room on a floor of the hospital. The plurality of sensor readings of the reading set preferably comprises from eight to thirty sensor readings for the transponder, and each sensor reading originates from a single stationary sensor positioned within the indoor facility. Each sensor reading is preferably a radio frequency transmission from the transponder. The step of obtaining a plurality of sensor readings from the transponder attached to the object preferably comprises, transmitting a radio frequency transmission from the transponder, the radio frequency transmission comprising a signal strength, link quality, time of transmission and identification of the transponder, receiving the radio frequency transmission at a plurality of stationary sensors positioned within the indoor facility, and transmitting the signal strength, the link quality, the time of transmission and the identification of the transponder from each of the plurality of stationary sensors to a server for processing.

Another object of the present invention is a system for providing real-time location information for a plurality of non-stationary objects within an indoor facility. The system includes a plurality of sensors, a plurality of transponders and a processing means. Each of the stationary sensors is positioned within the indoor facility. Each of the transponders is attached to one of the non-stationary objects. Each of the transponders has means for wirelessly transmitting to each of the stationary sensors transponder-specific data. The processing means processes the transponder-specific data to obtain a real-time reading set for the transponder. The processing means also

processes the real-time reading set to determine a first plurality of sensor readings. The first plurality of sensor readings corresponds to a physical region within the indoor facility having the highest average reading. The processor means then processes the first plurality of sensor readings, which are associated with the selected physical region, to select a zone within the physical region having the highest average reading. The processing means then calculates the position of the non-stationary object using the sensor readings from the stationary sensors positioned within the selected zone of the selected physical region.

The transponder-specific data preferably comprises a signal strength, link quality, time and identification of the transponder. In a preferred embodiment, the indoor facility is a hospital with the physical region preferably a floor of the hospital, and the selected zone is a room on a floor of the hospital. The processing means is preferably a server in communication with the plurality of stationary sensors through a network. Each transponder preferably transmits a radio frequency transmission of approximately 2.48 gigahertz, and each stationary sensor preferably communicates utilizing a 802.15.4 protocol. The system may further comprise means for eliminating those sensor readings not associated with (i.e., located within) the selected zone.

Another aspect of the present invention is a method for determining a location of an object within a predetermined environment. The method begins with transmitting a plurality of radio frequency signals for a wireless tracking device to a positioning engine. The wireless tracking device is attached to the object and each of the radio frequency signals corresponds to a fixed signal transmitter within the environment. Each radio frequency signal is processed to determine the location of the respective fixed signal transmitter. A probable region of the object is determined based on the location of a majority of the fixed signal transmitters for the plurality of radio frequency signals. The radio frequency signals that correspond to fixed signal transmitters located outside of the probable region of the object are eliminated from the location determination. The position of the object within the predetermined environment is calculated using only the radio frequency signals that correspond to fixed signal transmitters located within the probable region of the object.

The predetermined environment is preferably a hospital, and the probable region of the object is preferably a room in the hospital. The step of transmitting a plurality of radio frequency signals for a wireless tracking device to a positioning engine preferably comprises transmitting radio frequency signals from the wireless tracking device, each radio frequency signal comprising a signal strength, link quality, time of transmission and identification of the transponder, receiving the radio frequency signals at a plurality of stationary sensors positioned within the predetermined environment, and transmitting the signal strength, the link quality, the time of transmission and the identification of the wireless tracking device from each of the plurality of stationary sensors to a server for processing.

Yet another aspect of the present invention is a system for providing real-time location information for a plurality of non-stationary objects within an indoor facility. The system includes a mapped space and a processor. The mapped space is of a physical environment of the indoor facility. The processor includes means for updating the mapped space in response to received measurements of the physical environment from one or more stationary sensors located within the indoor facility, means for generating a plurality of location hypotheses for a non-stationary object within the physical environment, at least one of the location hypotheses computed in response to measurement received from the non-stationary object and the mapped space, and means for generating a location estimate based on one or more of the plurality of location hypotheses, wherein one or more of the plurality of location hypotheses are selected based on a probability associated respectively therewith. The probability is computed in association with known barriers in the physical space.

Brief Description Of The Drawings

FIG. 1 is schematic view of a system of the present invention.

FIG. 2 is a multi-floor view of a facility employing the system of the present invention.

FIG. 3 is a floor plan view of a single floor in a facility employing the system of the present invention.

FIG. 4 is a two-floor view of a facility including a tagged object and sensors of the system of the present invention.

FIG. 5 is a flow chart of a general method of the present invention.

FIG. 6 is a flow chart of a specific method of the present invention.

FIG. 7 is a flow chart of a specific method of the present invention.

FIG. 8 is a flow chart of a single sensor reading input.

Best Mode(s) For Carrying Out The Invention

As shown in FIGS 1-4, a system is generally designated 50. The system 50 is capable of determining real-time location of an object 100 within an indoor facility 70. The system 50 preferably includes a plurality of sensors 55, a plurality of bridges 56, a plurality of tags 60 and at least one server 65. One example of the components of the system 50 is disclosed in U.S. Patent Application Number 10/968814, filed on October 18, 2004 for a *Wireless Position Location And Tracking System*, which is hereby incorporated by reference in its entirety. A more specific example of the sensors 55 is disclosed in U.S. Patent Application Number 11/008802, filed on December 8, 2004 for a *Plug-In Network Appliance*, which is hereby incorporated by reference in its entirety. Another example of a system 50 is set forth in U.S. Patent Number 6751455 for a *Power-And Bandwidth-Adaptive In-Home Wireless Communications System With Power-Grid-Powered Agents And Battery-Powered Clients*, which is hereby incorporated by reference in its entirety.

The system 50 is preferably employed within an indoor facility 70 such as a business office, factory, home, hospital and/or government agency building. The system 50 is utilized to track and locate various objects positioned throughout the facility 70. The tags 60 continuously transmit signals on a predetermined time cycle, and these signals are received by sensors 55 positioned throughout the facility 70. The sensors 55 transmit the data to a bridge 56 for transmission to a server 65. If a sensor 55 is unable to transmit to a bridge 56, the sensor may transmit to another sensor 55 in a mesh network-like system for eventual transmission to a bridge 56. In a preferred embodiment, a transmission may be sent from a transmission distance of six sensors 55

from a bridge 56. The server 65 preferably continuously receives transmissions from the sensors 55 via the bridges 56 concerning the movement of objects 100 bearing a tag 60 within the facility 70. The server 65 processes the transmissions from the sensors 55 and calculates a real-time position for each of the objects 100 bearing a tag 60 within the facility 70. The real-time location information for each of the objects 100 bearing a tag 60 is preferably displayed on an image of a floor plan of the indoor facility 70, or if the facility 70 has multiple floors, then on the floor plan images of the floors of the facility 70. The floor plan image may be used with a graphical user interface so that an individual of the facility 70 is able to quickly locate objects 100 within the facility 70.

As shown in FIG. 1, the system 50 utilizes sensors 55 to monitor and identify the real-time position of non-stationary objects bearing or integrated with tags 60. The sensors 55a-f preferably wirelessly communicate with each other (shown as double arrow lines) and with a server 65 through a wired connection 66 via at least one bridge 56, such as disclosed in the above-mentioned U.S. Patent Application Number 11/008802, filed on December 8, 2004 for a *Plug-In Network Appliance*. The tags 60a-c transmit signals (shown as dashed lines) which are received by the sensors 55a-e, which then transmit signals to bridges 56 for eventual transmission to a server 65. The server 65 is preferably located on-site at the facility 70. However, the system 50 may also include an off-site server 65, not shown.

Each tag 60 preferably transmits a radio frequency signal of approximately 2.48 GigaHertz ("GHz"). The communication format is preferably IEEE Standard 802.15.4. Those skilled in the pertinent art will recognize that the tags 60 may operate at various frequencies without departing from the scope and spirit of the present invention.

As shown in FIGS. 2-4, the facility 70 is depicted as a hospital. The facility 70 has a multitude of floors 75a-c. An elevator 80 provides access between the various floors 75a, 75b and 75c. Each floor 75a, 75b and 75c has a multitude of rooms 90a-i, with each room 90 accessible through a door 85. Positioned throughout the facility 70 are sensors 55a-o for obtaining readings from tags 60a-d attached to or integrated into

non-stationary objects 100a, 100b (see FIGS. 2 and 4). A bridge 56 is also shown for receiving transmissions from the sensors 55 for processing by the server 65.

As shown in FIG. 4, the tag 60a is attached to movable bed 100a positioned on an upper floor 75c. The tag 60a transmits a signal which is received by sensors 55a, 55b and 55c. If the signal to sensor 55c is the strongest, then an analysis of the readings from the sensors 55a-c may place the tag 60a, and thus the movable bed 100a, at position 60' on the lower floor 75b. This type of faulty reading would likely occur with triangulation. To prevent such a faulty positioning reading, the present invention processes the readings preferably according to one of the methods illustrated in FIGS. 5-7, which would eliminate the reading from sensor 55c from the location calculation for movable bed 100a.

A general method 200 of the present invention is illustrated in FIG. 5. At block 202, the sensors 55 of the system 50 generate readings from the tags 60. These single sensor reading inputs 600 are illustrated in FIG. 8. As shown in FIG. 8, the inputs preferably include the tag identification 604, the signal strength 606, the link quality 608 and the time of the reading 610, which are inputted as a single sensor reading 602. At block 204, a plurality of readings sets are generated from the sensor readings. In a preferred embodiment, each of the plurality of readings sets represents an area of a facility 70. At block 206, the readings are further sorted by a particular zone of the facility 70 thereby eliminating readings that may lead to an incorrect location. In a preferred embodiment, a zone is a subset of an area. At block 208, the zone with the highest average reading is selected for calculation of the position of the object 100, again eliminating readings that may lead to an incorrect reading. At block 210, the location of the object 100 is calculated based on the readings from the selected zone.

A more specific method 300 of the present invention is set forth in FIG. 6. At block 302, the sensors 55 of the system 50 generate readings from the tags 60. As discussed above, the single sensor reading inputs 600 are illustrated in FIG. 8. At block 304, a reading set is generated for readings from a single tag 60. The generation of the reading set is typically in response to an inquiry from a user of the system 50 in search of an object 100 bearing tag 60. At decision block 306, the server 65 determines if

there is sufficient data to proceed with the location analysis. If there is insufficient data, the method is restarted at block 302. If there is sufficient data, then the method proceeds to block 308. At block 308, the reading sets are separated by floor 75 of the facility 70. At block 310, the floor 75 with the highest average reading set is selected for further processing. At block 312, the readings for the selected floor are sorted by zones. Each zone may represent any physical boundary on the selected floor 75 of the facility 70. Preferably, the zones represent a room 90, station 95 or other easily determined physical location. At block 314, the zone with the highest average reading is selected. At block 316, the location of the object 100 is calculated based on the readings from the selected zone. At block 318, the location is inputted to the location database for dissemination to users of the system to locate the object 100.

An even more specific method 400 of the present invention is set forth in FIG. 7. At block 402, the sensors 55 of the system 50 generate readings from the tags 60. As discussed above, the single sensor reading inputs 600 are illustrated in FIG. 8. At block 404, a reading set is generated for readings from a single tag 60. The generation of the reading set is typically in response to an inquiry from a user of the system 50 in search of an object 100 bearing tag 60. At decision block 406, the server 65 determines if there is sufficient data to proceed with the location analysis. If there is insufficient data, the method is restarted at block 402. If there is sufficient data, then the method proceeds to block 408. At block 408, the reading sets are separated by floor 75 of the facility 70. At block 410, the floor 75 with the highest average reading set is selected for further processing. At block 412, the readings for the selected floor are sorted by zones. Each zone may represent any physical boundary on the selected floor 75 of the facility 70. Preferably, the zones represent a room 90, station 95 or other easily determined physical location. At block 414, the zone with the highest average reading is selected. At block 416, the location of the object 100 is calculated based on the readings from the selected zone.

At decision block 418, the server 65 inquires if the new calculated location is consistent with available data for the object 100. The available data includes the motion sensor state of the object 100 which is tracked at block 424. If the motion

sensor has not detected movement of the object 100, then that is one indication that the new calculated location is in error. However, if the motion sensor has detected movement of the object 100, then that is one indication that the new calculated location is correct. Additional data for the decision block 418 includes recently calculated locations for the object 100 which are available from database 426. Yet further data available for decision block 418 is data from the possible hypotheses database 428. The possible hypotheses database includes data such as the timing between the last calculated location and the new calculated location. If the object 100 has moved one end of the facility 70 to another end of the facility 70 within seconds, then the new calculated location may be in error. If the response to decision block 418 is yes, then at block 420 the location is inputted to the location database for dissemination to users of the system to locate the object 100. If the response to decision block 418 is no, then the new calculated location is held as an unproven hypothesis at block 422.

The following example illustrates the information that is utilized and eliminated in practicing the present invention.

TABLE ONE

Sensor #	Signal Strength dB	Link Quality	Time	Sensor Location (floor/region)
1	-95	-95	09/14/06 11:22:35	5/B
2	-10	-10	09/14/06 11:22:35	4/C
3	-20	-20	09/14/06 11:22:36	4/C
4	-25	-25	09/14/06 11:22:35	4/C
5	-40	-40	09/14/06 11:22:36	4/C
6	-50	-50	09/14/06	4/C

			11:22:36	
7	-70	-70	09/14/06 11:22:36	4/D
8	-80	-80	09/14/06 11:22:36	4/D
9	-90	-90	09/14/06 11:22:37	4/E
10	-95	-95	09/14/06 11:22:37	4/E

TABLE TWO

Floor	Average Reading per Floor
2	N/A
3	-120
4	-30
5	-85

TABLE THREE

Region	Peaks	Average Reading per Region
C	-20	-20
D	-10	-70
E	-70	-95

As shown in Table One, the signal strength from each tag 60 is provided in milli-decibels ("dBm") with a full strength value of zero, which is equal to 1 milli-Watt of power. The Link Quality value is provided as a similar value as the signal strength. The time is a date stamp of the time and date that the signal is received by the sensor 55. The sensor location is preferably a floor and region on the floor. In a preferred embodiment, the regions on the floors overlap each other. The regions are preferably determined based on the facility 70.

In Table One, ten readings from sensors 55 positioned on various floors of the facility 70. Each of the readings is transmitted from a single tag 60 to the sensors 60. The sensors 60 transmit the data from the tag 60 to the server 65 via bridges 56. The server 65 uses the data to calculate the location of the object 100 as discussed. The sensor location may also be provided in terms of a X-Y position which is based on a floor plan image of each floor of the facility 70. The X-Y position may be based on the pixel location on the image of the floor plan.

The average reading from all of the sensors 55 on each floor is provided in Table Two. More specifically, if the fifth floor has ten sensors 55 that each received a signal from a specific tag 60, then the readings from those ten sensors 55 are averaged to obtain the average reading per floor value provided in Table Two. The readings from the floor with the highest value are then further processed to determine the location of the object 100. The readings from the sensors 55 on the other floors are eliminated from the calculation for the location of the object 100.

The average reading from all of the sensors 55 in each region on the selected floor is provided in Table Three. As mentioned above, the regions preferably overlap so that a single sensor 55 may be in two or more regions, and used in the average reading for both regions. The peak reading for each region is also set forth in Table Three. In an alternative embodiment, if the peak reading exceeds a threshold, then that region is selected even if the average readings for that region are less than another region. In calculating the location of the object 100, the highest readings within a selected region are used for the calculation. The number of readings used preferably ranges from 2 to 10, and is most preferably 3 to 5. The more readings used in the calculation, the longer the processing time for the calculation. Thus, using 10 readings may provide a more accurate location, however, the processing time will be longer than using 3 readings. In a preferred embodiment, a radial basis function is utilized in calculating the location of the object 100. The location of the object 100 is preferably conveyed as an XY coordinate on a floor plan image of the facility 70.

Claims

1. A method for determining a real-time location of an object within an indoor facility, the method comprising:

obtaining a plurality of sensor readings from a tag attached to the object;

generating a reading set comprising the plurality of sensor readings;

sorting the reading set by a plurality of physical regions;

selecting a first physical region of the plurality of physical regions, the first physical region composed of a first plurality of sensor readings having the highest average signal strength;

sorting the first plurality of sensor readings into a second plurality of sensor readings, each of the second plurality of sensor readings corresponding to a zone within the first physical region;

selecting a selected zone having the highest average reading; and

calculating a real-time location of the object from a plurality of the highest sensor readings from the second plurality of sensor readings corresponding to the selected zone.

2. The method according to claim 1 wherein the sensor readings comprise signal strength, link quality, time and identification of the tag.

3. The method according to claim 1 further comprising displaying the real-time location of the object on a graphical user interface.

4. The method according to claim 1 further comprising comparing the calculated real-time location of the object to a previously calculated location for the object.

5. The method according to claim 4 further comprising monitoring the motion state of the object to confirm movement of the object from the previously calculated location to the real-time location.

6. The method according to claim 1 wherein the indoor facility is a hospital, each of the plurality of physical regions is a floor of the hospital, and the selected zone is a room on a floor of the hospital.

7. The method according to claim 1 wherein the plurality of sensor readings of the reading set comprises from eight to thirty sensor readings for the tag, and each of the plurality of sensor readings originates from a single stationary sensor positioned within the indoor facility.

8. The method according to claim 1 wherein each of the plurality of sensor readings is a radio frequency transmission from the tag.

9. The method according to claim 1 wherein obtaining a plurality of sensor readings from a tag attached to the object comprises:

transmitting a radio frequency transmission from the tag comprising signal strength, link quality, time of transmission and identification of the tag;

receiving the radio frequency transmission at a plurality of stationary sensors positioned within the indoor facility; and

transmitting the signal strength, the link quality, the time of transmission and the identification of the tag from each of the plurality of stationary sensors to a server for processing.

10. A system for providing real-time location information for a plurality of non-stationary objects within an indoor facility, the system comprising:

a plurality of stationary sensors, each of the plurality of stationary sensors positioned within the indoor facility;

a plurality of tags, each of the plurality of tags attached to one of the plurality of non-stationary objects, each of the plurality of tags having means for wirelessly transmitting to each of the plurality of stationary sensors tag specific data; and

means for processing the tag specific data to obtain a real-time reading set for the tag, to process the reading set to determine a first plurality of sensor readings with the highest average reading, to select a physical region within the indoor facility having the highest average reading, to select a zone within the physical region having the highest average reading, and to calculate the position of an object from the sensor readings positioned within the selected zone.

11. The system according to claim 10 wherein the tag specific data comprises signal strength, link quality, time and identification of the tag.

12. The system according to claim 10 wherein the indoor facility is a hospital, the physical region is a floor of the hospital, and the selected zone is a room on a floor of the hospital.

13. The system according to claim 10 wherein the processing means is a server in communication with the plurality of stationary sensors through at least one bridge.

14. The system according to claim 10 wherein each of the plurality of tags transmits a radiofrequency transmission of approximately 2.48 GigaHertz, and each of the plurality of stationary sensors communicates utilizing a 802.15.4 protocol.

15. The system according to claim 10 further comprising means for eliminating sensor readings not associated with the selected zone.

16. A method for determining a location of an object within a predetermined environment, the method comprising:

transmitting a plurality of radiofrequency signals for a wireless tracking device to a positioning engine, the wireless tracking device attached to the object, each of the plurality of radiofrequency signals corresponding to a fixed signal transmitter within the environment;

processing each of the plurality of radiofrequency signals to determine the location of the fixed signal transmitter for each of the plurality of radiofrequency signals;

determining a probable region of the object based on the location of a majority of the fixed signal transmitter for each of the plurality of radiofrequency signals;

eliminating any of the plurality of radiofrequency signals corresponding from a fixed signal transmitter located outside of the probable region of the object; and

calculating the position of the object within the predetermined environment using only the plurality of radiofrequency signals corresponding to a fixed signal transmitter within the probable region of the object.

17. The method according to claim 16 wherein the predetermined environment is a hospital and the probable region of the object is a room in the hospital.

18. The method according to claim 16 wherein transmitting a plurality of radio frequency signals for a wireless tracking device to a positioning engine comprises:

transmitting radio frequency signals from the wireless tracking device comprising signal strength, link quality, time of transmission and identification of the wireless tracking device;

receiving the radio frequency signals at a plurality of stationary sensors positioned within the predetermined environment; and

transmitting the signal strength, the link quality, the time of transmission and the identification of the wireless tracking device from each of the plurality of stationary sensors to a server for processing.

19. A system for providing real-time location information for a plurality of non-stationary objects within an indoor facility, the system comprising:

a mapped space of a physical environment of the indoor facility; and

a processor comprising

means for updating the mapped space in response to received measurements of the physical environment from one or more stationary sensors located within the indoor facility,

means for generating a plurality of location hypotheses for a non-stationary object within the physical environment, at least one of the location hypotheses computed in response to measurement received from the non-stationary object and the mapped space, and

means for generating a location estimate based on one or more of the plurality of location hypotheses, wherein one or more of the plurality of location hypotheses are selected based on a probability associated respectively therewith, and wherein a probability is computed in association with known barriers in the physical space.

20. The system according to claim 19 wherein the indoor facility is a hospital.

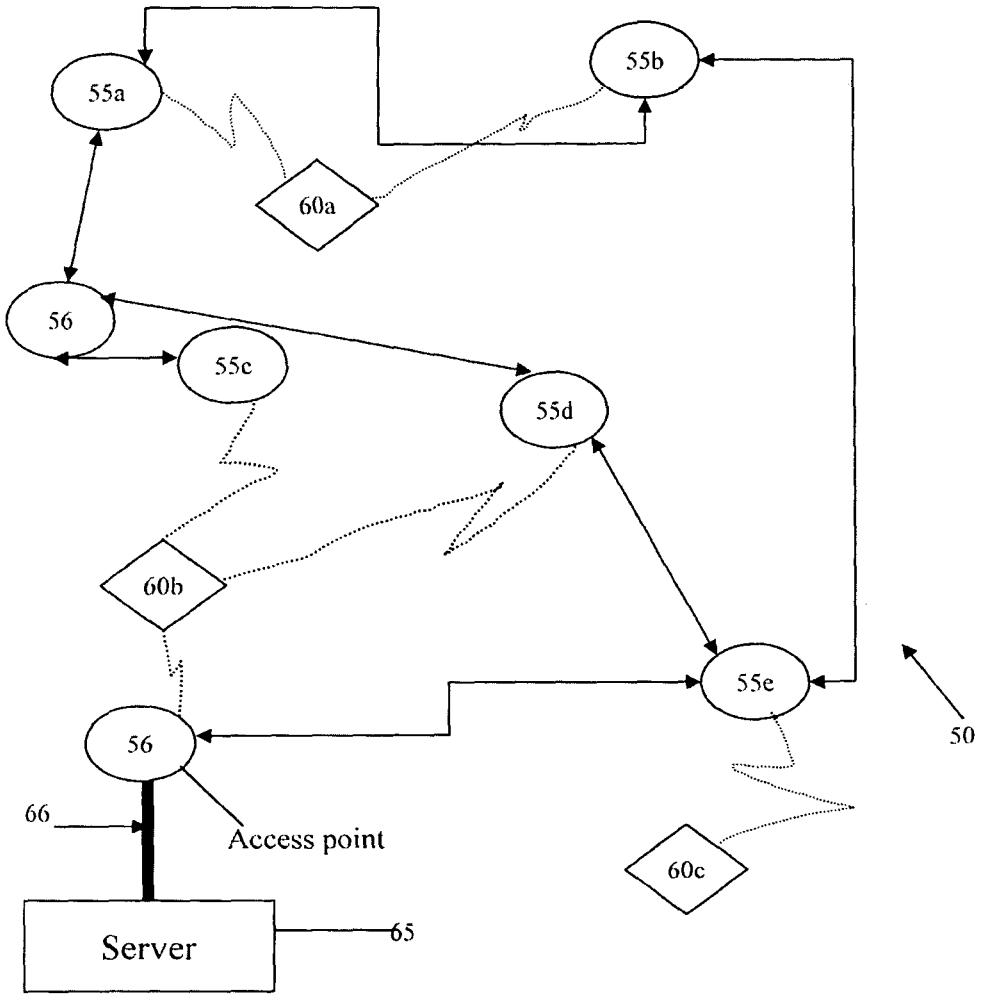
55a
55b
60a
56
55c
55d
60b
55e
50
56
66
Access point
60c
Server
65

FIG. 1

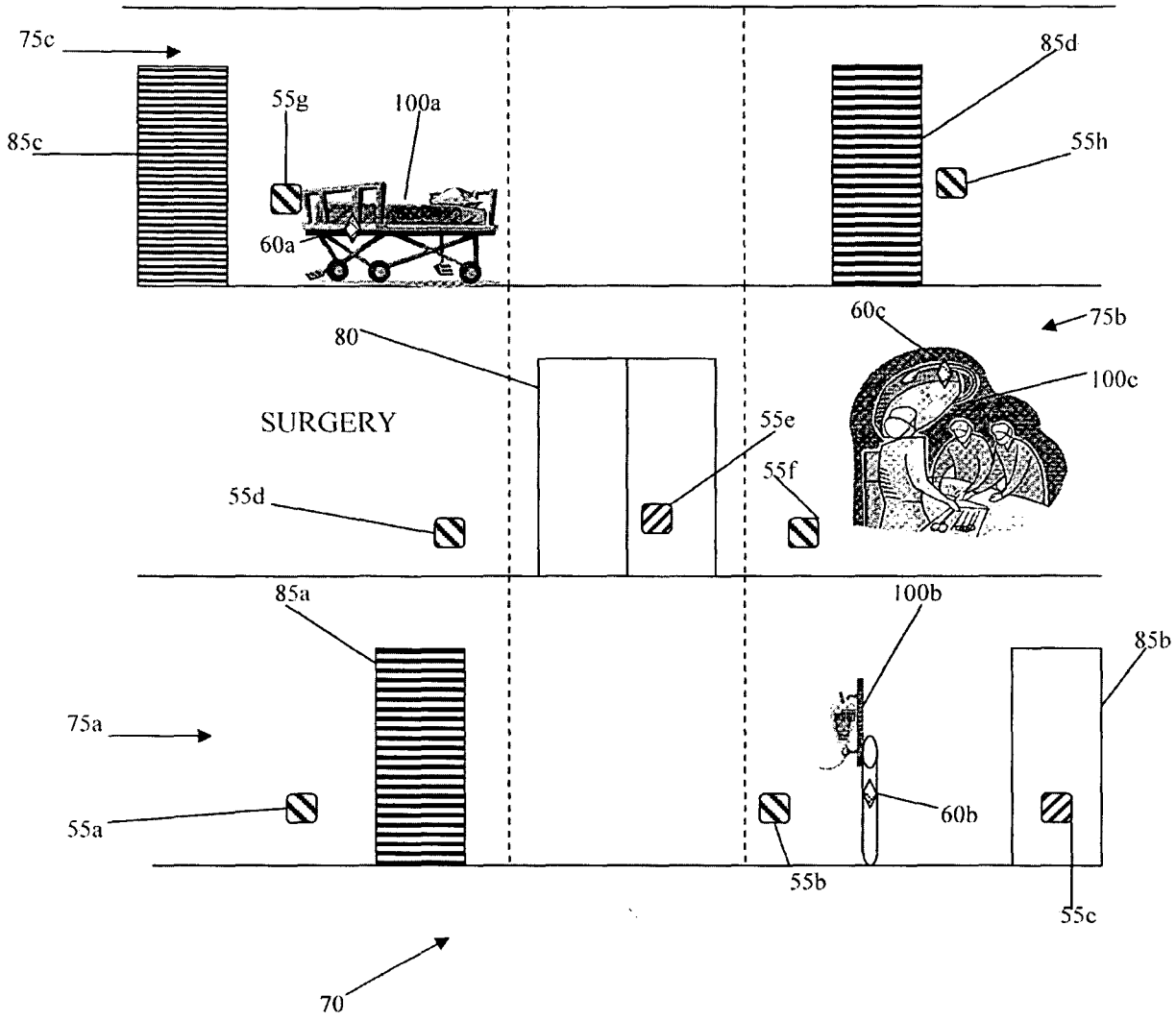
75c
85c
55g
100a
60a
85d
55h
80
SURGERY
55d
55e
55f
60c
75b
100c
85a
75a
55a
100b
85b
60b
55b
55c
70

FIG. 2

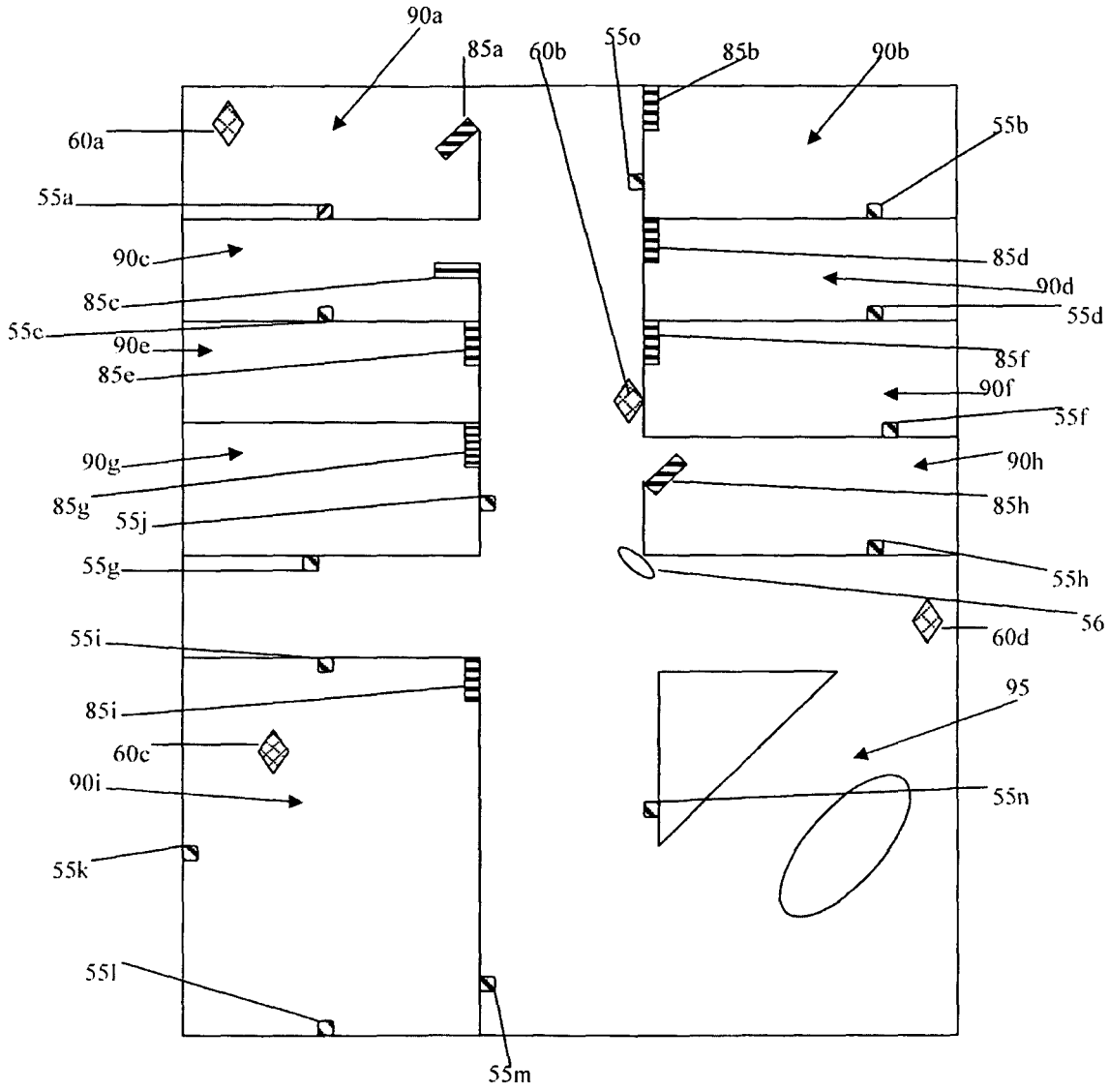
90a
85a
60b
55o
85b
90b
60a
55b
55a
90c
85d
90d
85c
55d
55c
90e
85f
85e
90f
55f
90g
90h
85g
85h
55j
55h
55g
56
60d
55i
95
85i
60c
55n
90i
55k
55l
55m

FIG. 3

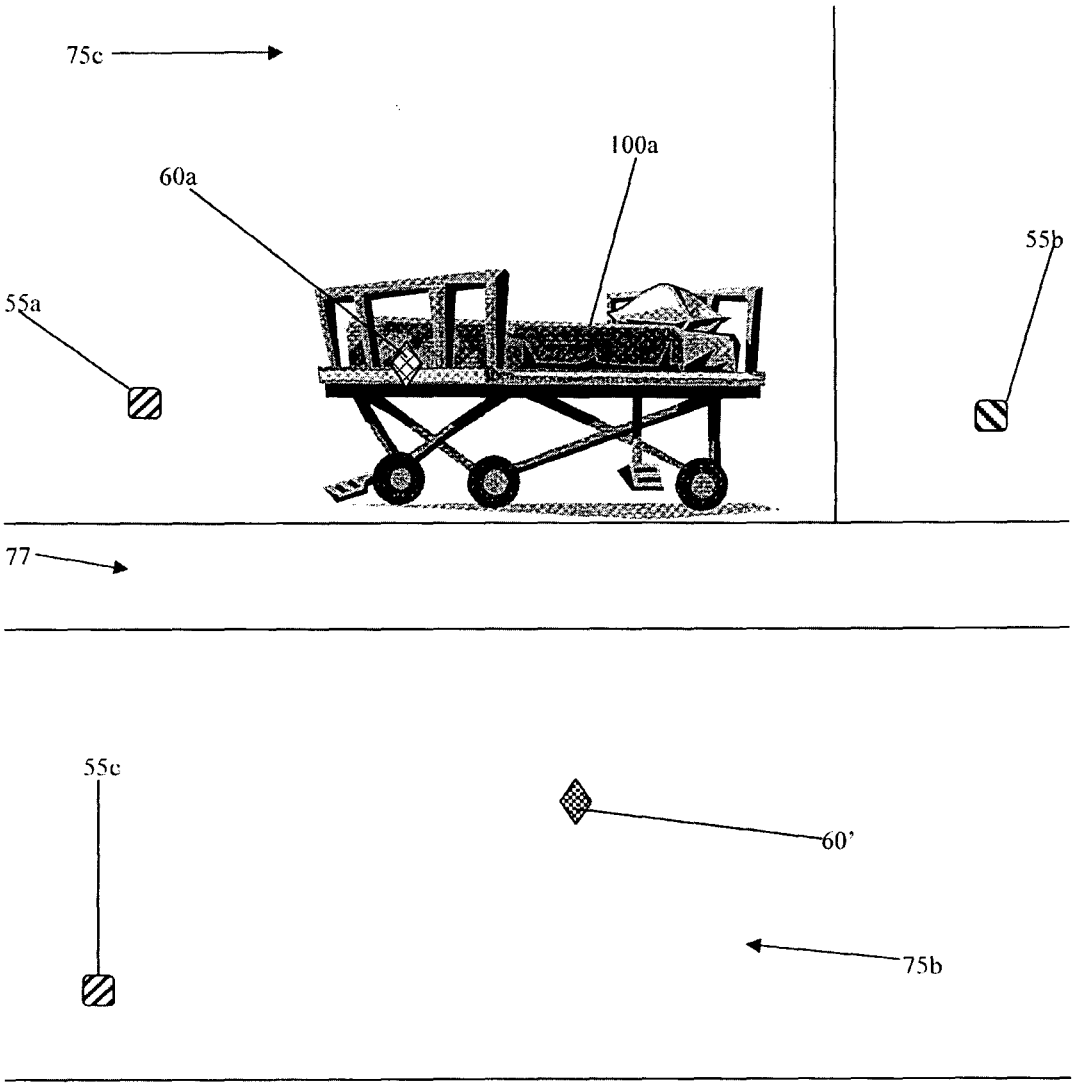

FIG. 4

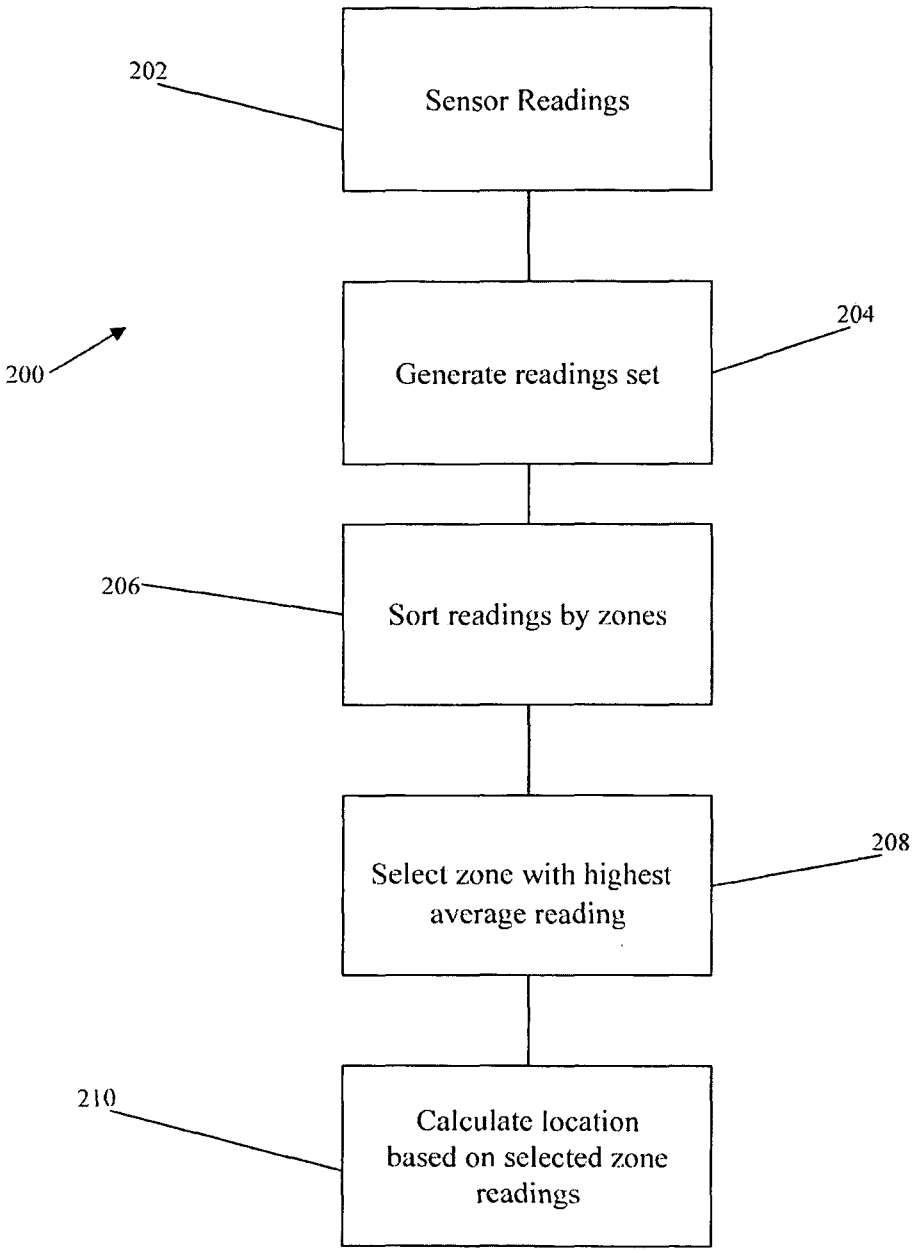
202
Sensor Readings
200
204
Generate readings set
206
Sort readings by zones
208
Select zone with highest average reading
210
Calculate location based on selected zone readings

FIG. 5

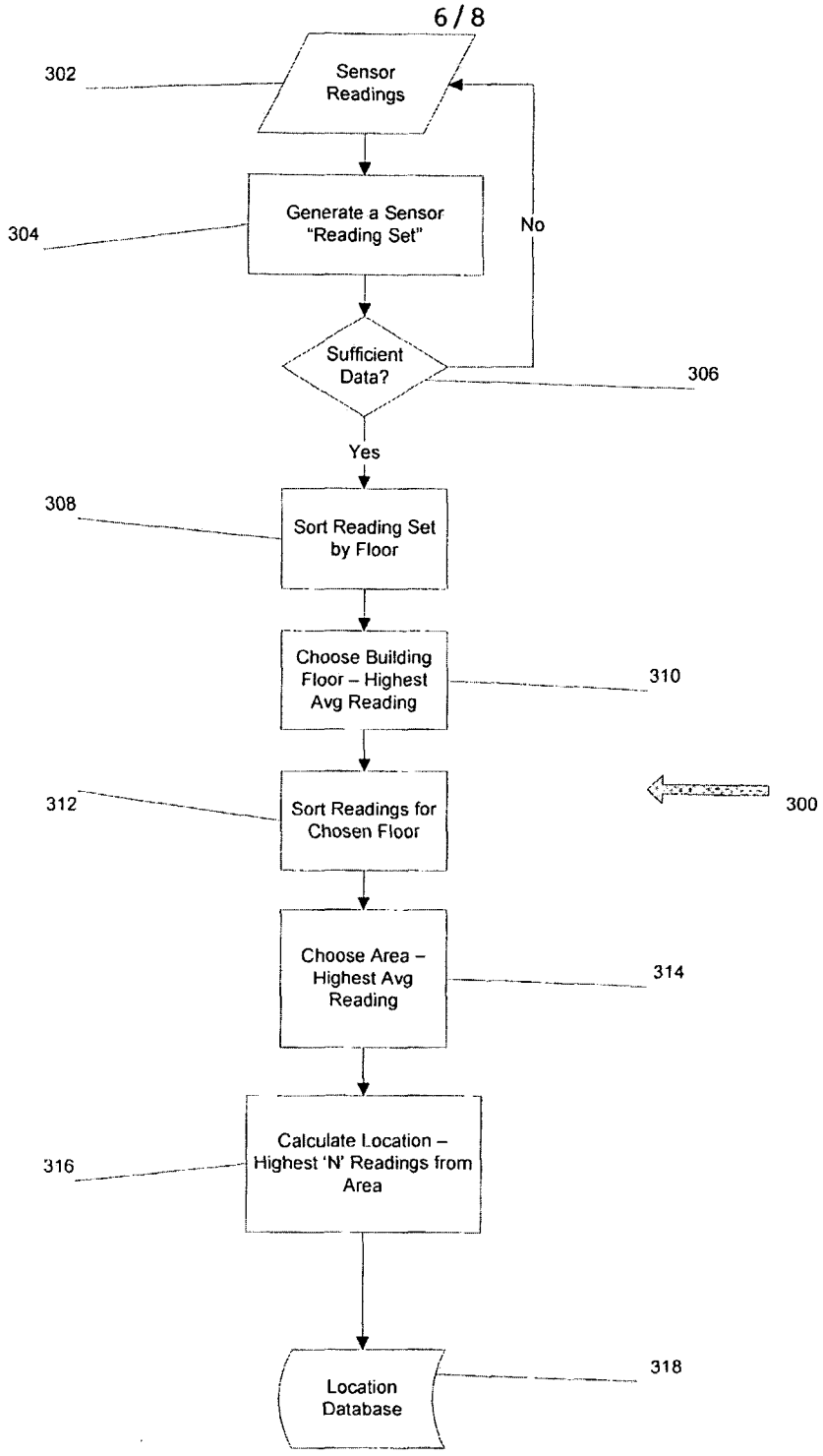
302
Sensor Readings
304
Generate a Sensor "Reading Set"
No
Sufficient Data?
306
Yes
308
Sort Reading Set by Floor
Choose Building Floor – Highest Avg Reading
310
312
Sort Readings for Chosen Floor
300
Choose Area – Highest Avg Reading
314
316
Calculate Location – Highest 'N' Readings from Area
318
Location Database

FIG. 6

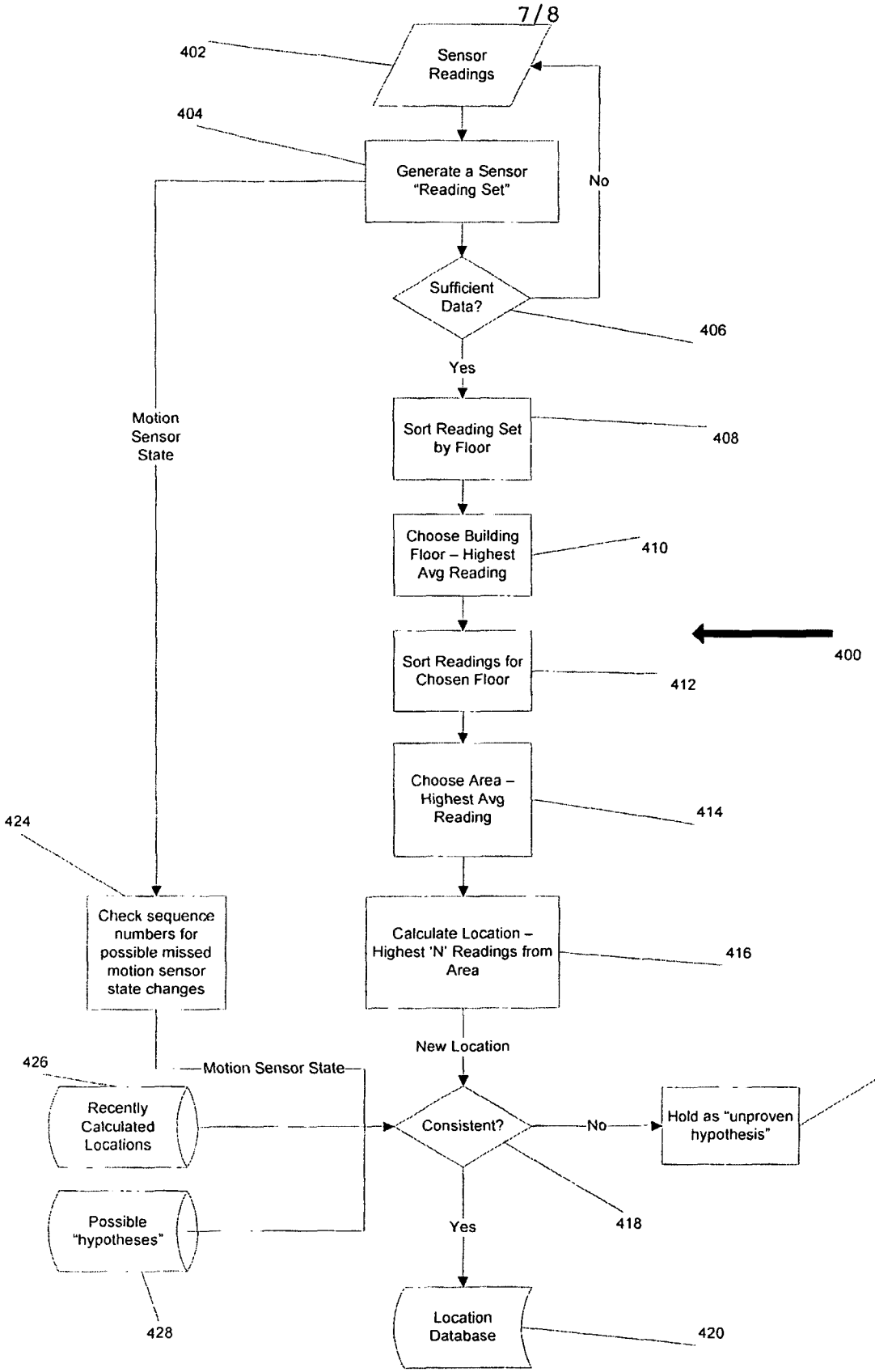
402
Sensor Readings
404
Generate a Sensor "Reading Set"
No
Sufficient Data?
406
Yes
Motion Sensor State
Sort Reading Set by Floor
408
Choose Building Floor – Highest Avg Reading
410
Sort Readings for Chosen Floor
412
400
Choose Area – Highest Avg Reading
414
424
Check sequence numbers for possible missed motion sensor state changes
Calculate Location – Highest 'N' Readings from Area
416
New Location
426
Motion Sensor State
Recently Calculated Locations
Consistent?
No
Hold as "unproven hypothesis"
422
Possible "hypotheses"
Yes
418
428
Location Database
420

FIG. 7

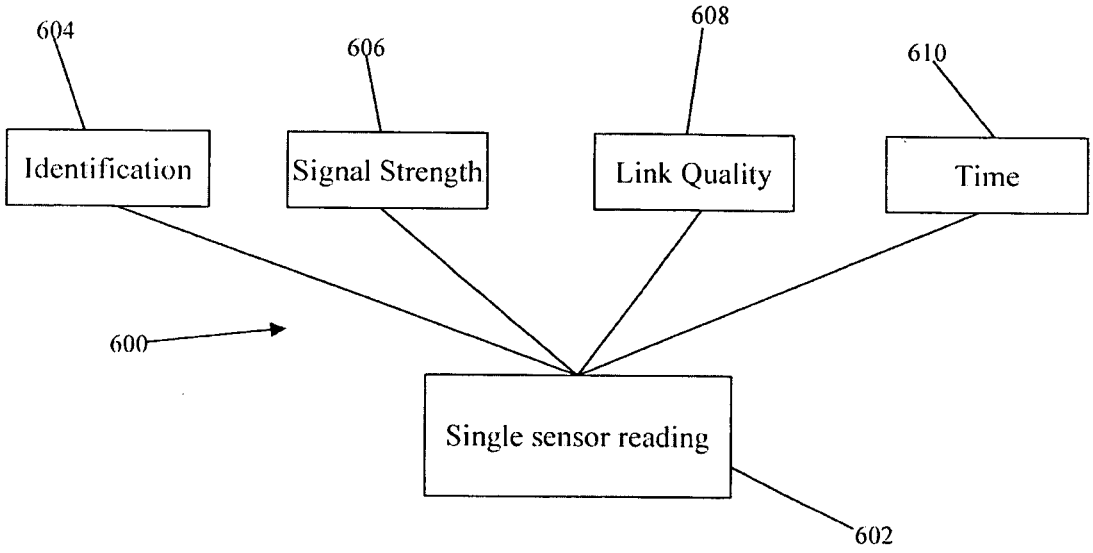
604
606
608
610
Identification
Signal Strength
Link Quality
Time
600
Single sensor reading
602

FIG. 8

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
AWP003-PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2007/089194	**31 DECEMBER 2007 (31.12.2007)**	07 FEBRUARY 2007 (07.02.2007)

Applicant

Awarepoint Corporation et al

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of **3** sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of :
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. **2**
      ☒ as suggested by the applicant.
      ☐ because the applicant failed to suggest a figure.
      ☐ because this figure better characterizes the invention.
   b. ☐ none of the figure is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/089194

A. CLASSIFICATION OF SUBJECT MATTER

H04B 17/00(2006.01)i, G01S 5/02(2006.01)i, H04B 7/26(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 H04B, G01S, H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS(KIPO internal) :"position location, wireless tracking, sensor"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7126951 B2 (BELCEA et al.) 24 Oct. 2006 Abstract, Figs.1, 4-7	1-20
A	US 7053830 B2 (KRUMM et al.) 30 May 2006 Abstract, Fig3-4	1-20
A	US 2006-0063523 A1 (MCFARLAND) 23 Mar. 2006 Abstract, Fig.5	1-20
A	US 6952574 B2 (TEALDI et al.) 04 Oct. 2005 Abstract, Fig.7	1-20
A	US 6738628 B1 (MCCALL et al.) 18 May 2004 Abstract, Figs. 3-4, claim 1	1-20
A	US 06799047B1 (BAHL et al.) 28 Sep. 2004 Abstract, Fig. 5-8	1-20
A	US 6259406 B1 (SUGIURA et al.)10 Jul. 2001 Abstract, Fig.12	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 MAY 2008 (26.05.2008)	**26 MAY 2008 (26.05.2008)**

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
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Authorized officer

LEE, Jin Ick

Telephone No. 82-42-481-5770

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2007/089194

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US07126951B2	24.10.2006	US20040246926A1	09.12.2004
US07053830B2	30.05.2006	US2005270235AA US7053830BB	08.12.2005 30.05.2006
US2006063523A1	23.03.2006	None	
US06952574B2	04.10.2005	US20040185822A1 WO2004079925A2 WO2004079925A3	23.09.2004 16.09.2004 31.03.2005
US06738628B1	18.05.2004	GB2353910A1 GB9920722A0	07.03.2001 03.11.1999
US06799047BA	28.09.2004	None	
US 6259406B1	10.10.2001	None	