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(54) **SYSTEM AND METHOD FOR LOCATING OBJECTS**

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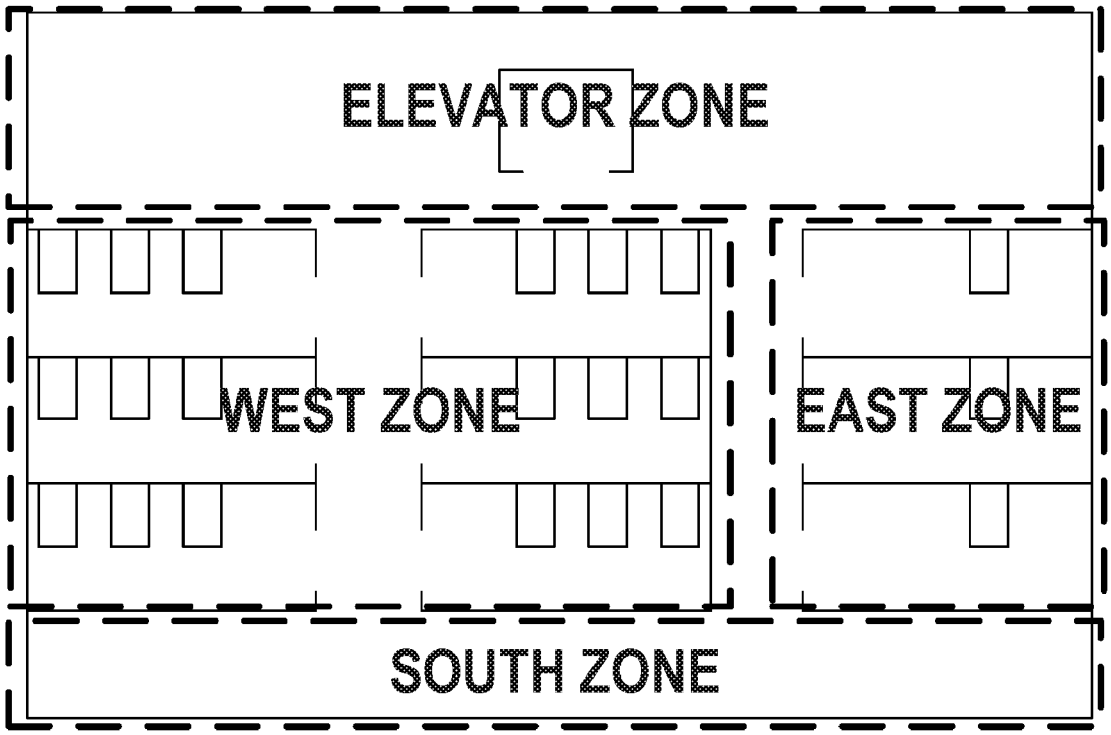
G01S 1/68	(2006.01)
G01S 5/02	(2006.01)

(52) **U.S. Cl.**

CPC ***G01C 21/206*** (2013.01); ***G01S 5/0252*** (2013.01); ***G01S 1/68*** (2013.01)

(57) **ABSTRACT**

A tag, and a method of operation of a tag, for directing a person toward a target asset that is located in a zone within a facility. The tag presents to the person a description of the target asset and directions for reaching the zone, seeks beacon signals from a beacon attached to the target asset, and produces homing directions for approaching the target asset.



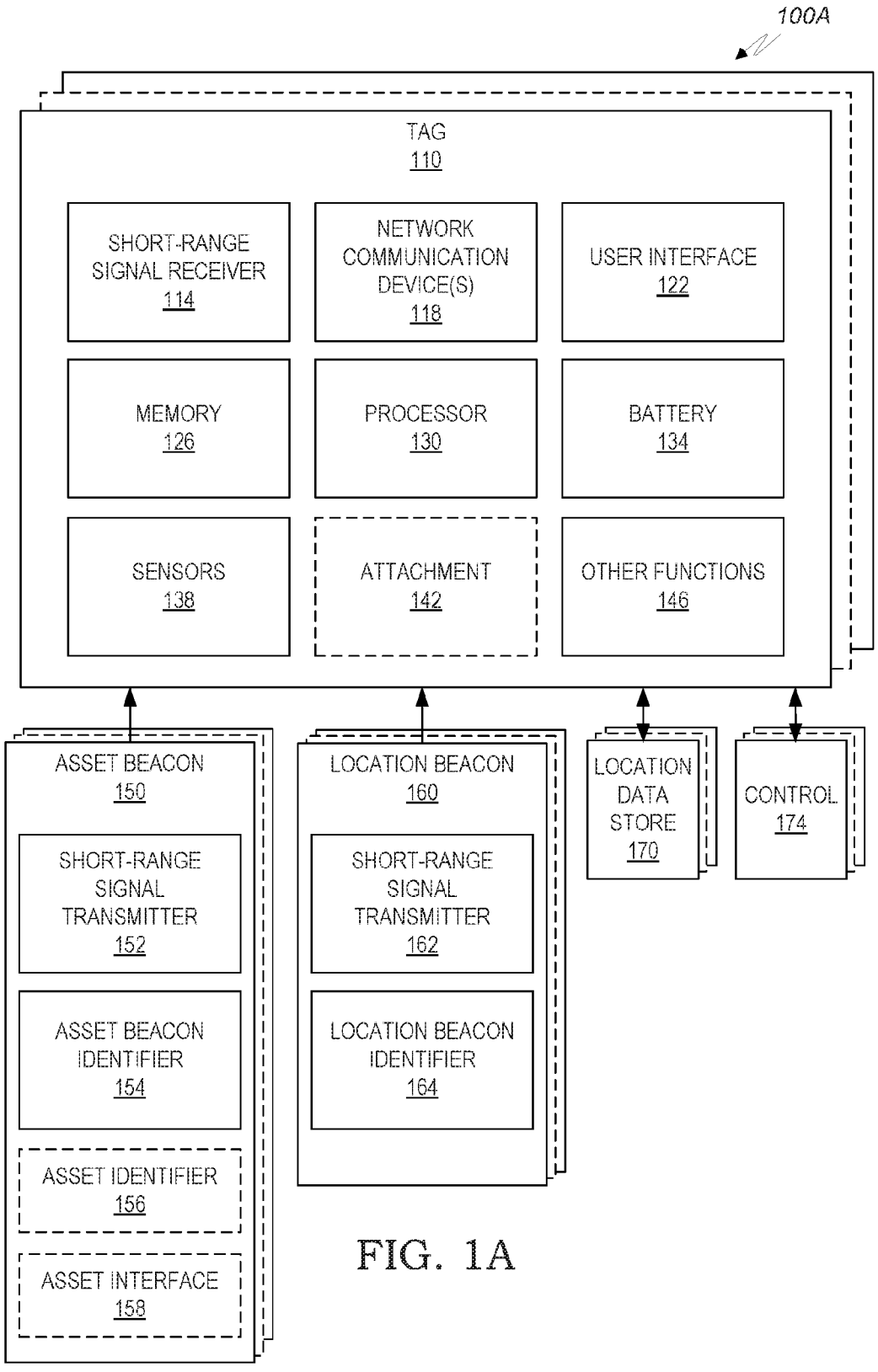

100A
TAG
110
SHORT-RANGE SIGNAL RECEIVER
114
NETWORK COMMUNICATION DEVICE(S)
118
USER INTERFACE
122
MEMORY
126
PROCESSOR
130
BATTERY
134
SENSORS
138
ATTACHMENT
142
OTHER FUNCTIONS
146
ASSET BEACON
150
SHORT-RANGE SIGNAL TRANSMITTER
152
ASSET BEACON IDENTIFIER
154
ASSET IDENTIFIER
156
ASSET INTERFACE
158
LOCATION BEACON
160
SHORT-RANGE SIGNAL TRANSMITTER
162
LOCATION BEACON IDENTIFIER
164
LOCATION DATA STORE
170
CONTROL
174

FIG. 1A

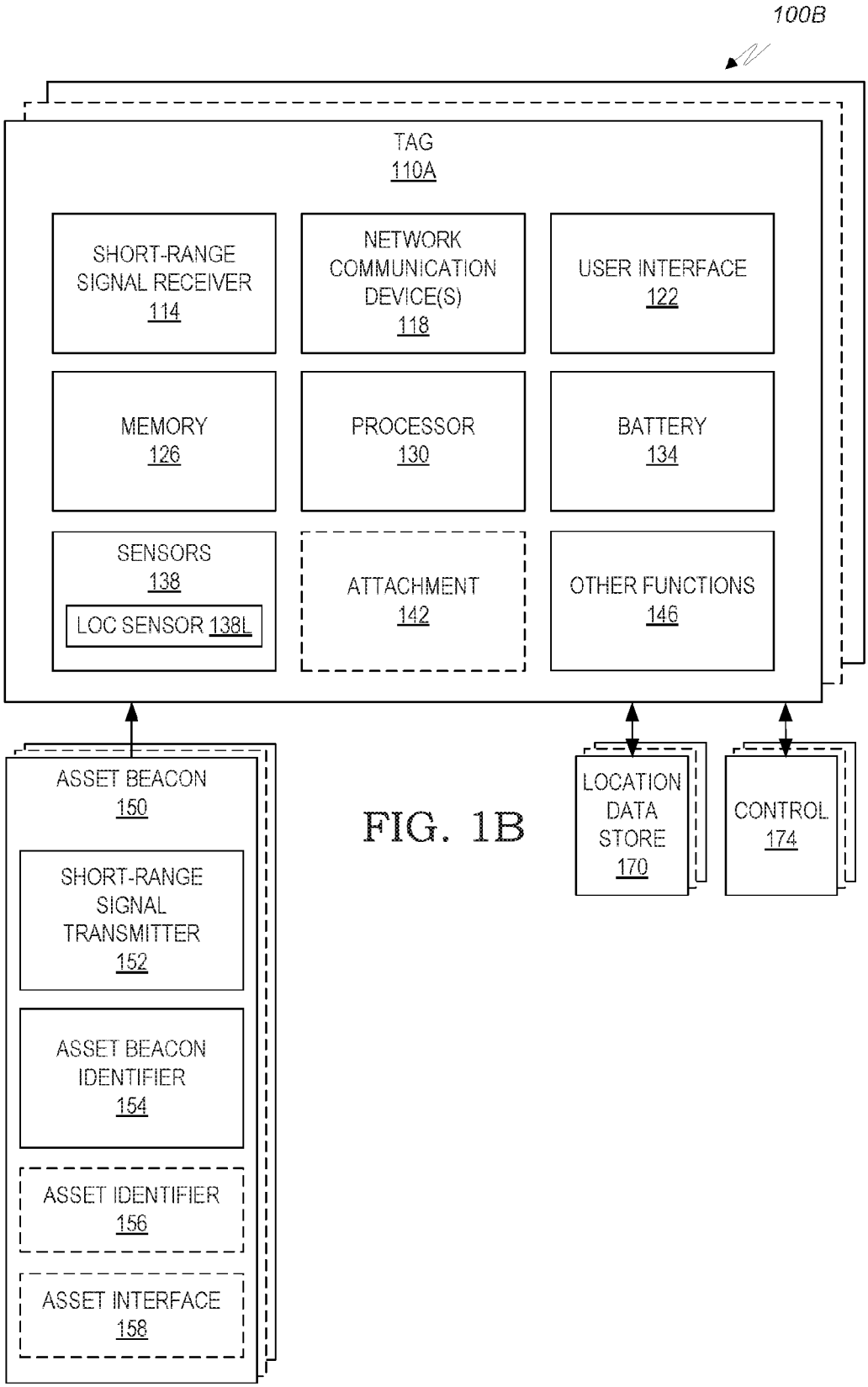

100B
TAG
110A
SHORT-RANGE SIGNAL RECEIVER 114
NETWORK COMMUNICATION DEVICE(S) 118
USER INTERFACE 122
MEMORY 126
PROCESSOR 130
BATTERY 134
SENSORS 138
LOC SENSOR 138L
ATTACHMENT 142
OTHER FUNCTIONS 146
ASSET BEACON 150
SHORT-RANGE SIGNAL TRANSMITTER 152
ASSET BEACON IDENTIFIER 154
ASSET IDENTIFIER 156
ASSET INTERFACE 158
LOCATION DATA STORE 170
CONTROL 174

FIG. 1B

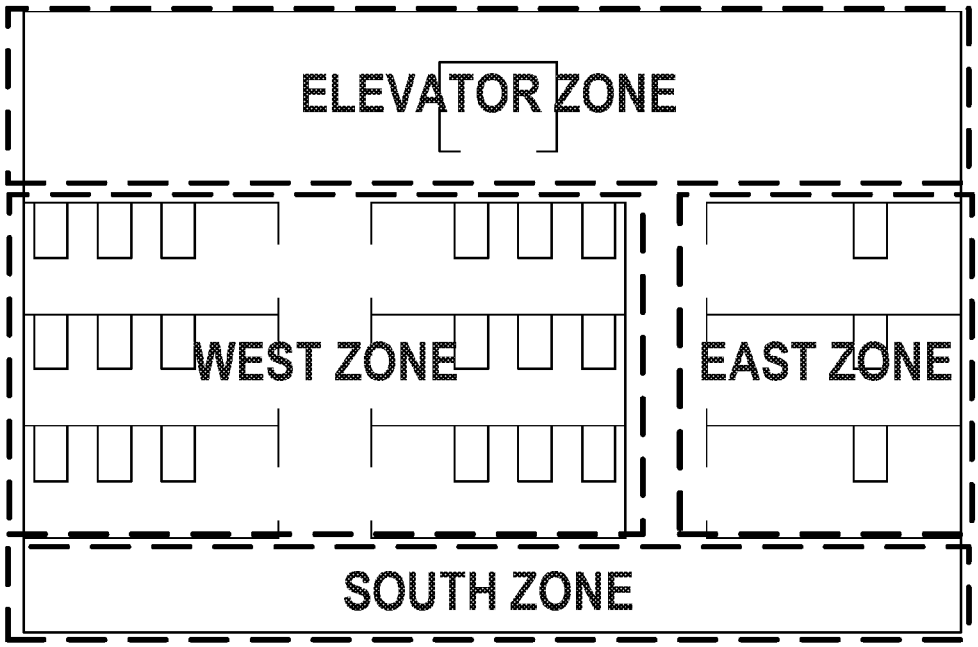

ELEVATOR ZONE
WEST ZONE
EAST ZONE
SOUTH ZONE

FIG. 2A

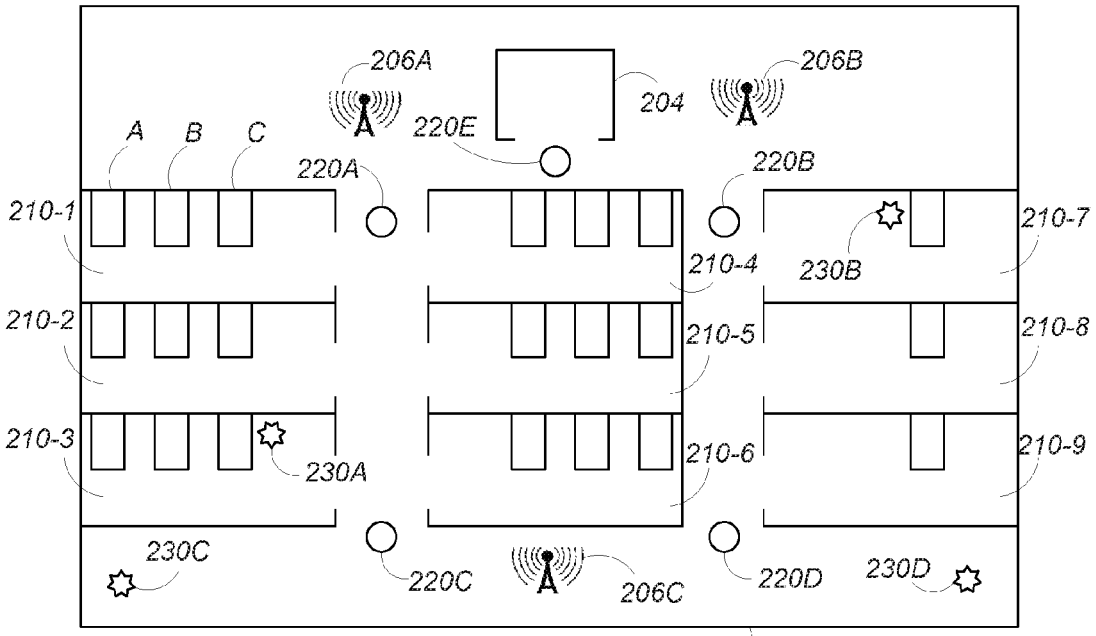

206A
204
206B
A
B
C
220E
220A
220B
210-1
210-4
230B
210-7
210-2
210-5
210-8
210-3
230A
210-6
210-9
230C
220C
206C
220D
230D
200B

FIG. 2B

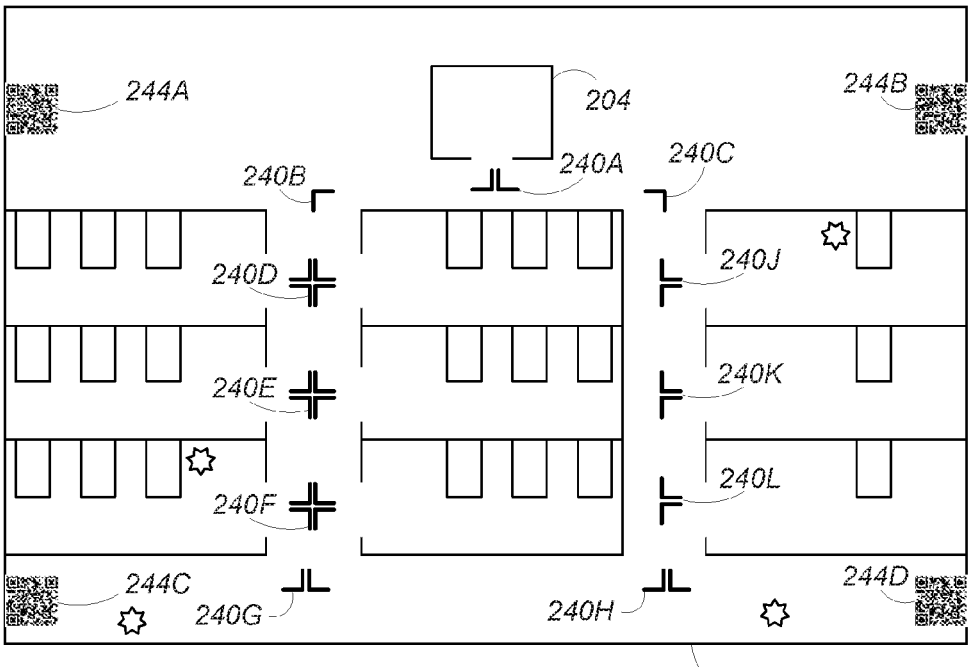

244A
204
244B
240B
240A
240C
240D
240J
240E
240K
240F
240L
244C
240G
240H
244D
200C

FIG. 2C

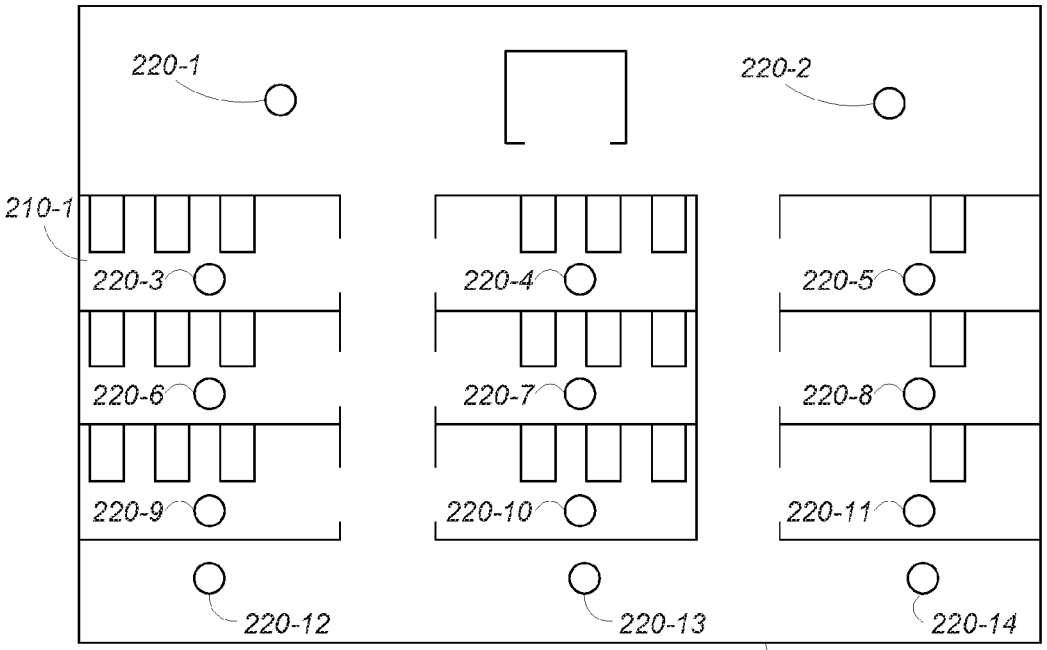

220-1
220-2
210-1
220-3
220-4
220-5
220-6
220-7
220-8
220-9
220-10
220-11
220-12
220-13
220-14
200D

FIG. 2D

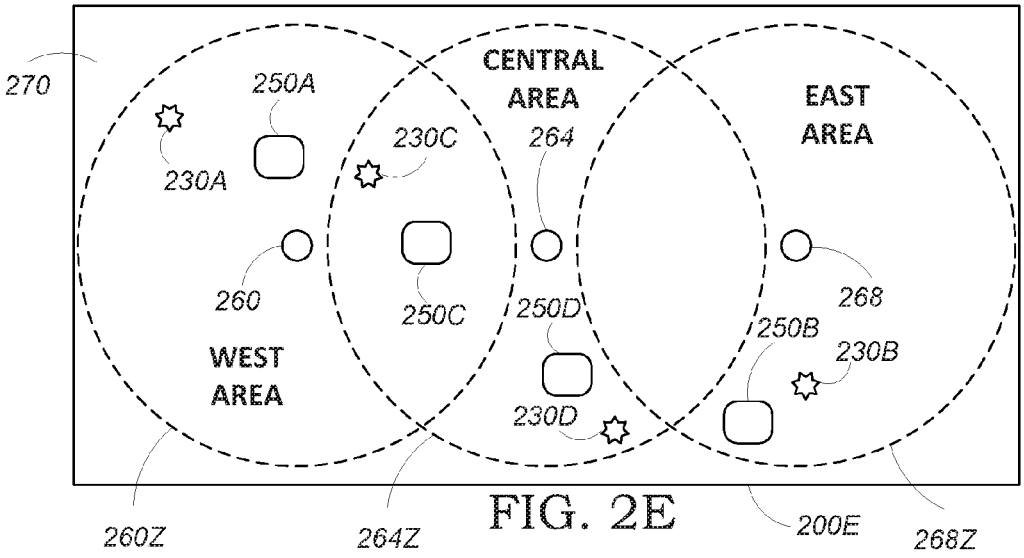


FIG. 2E

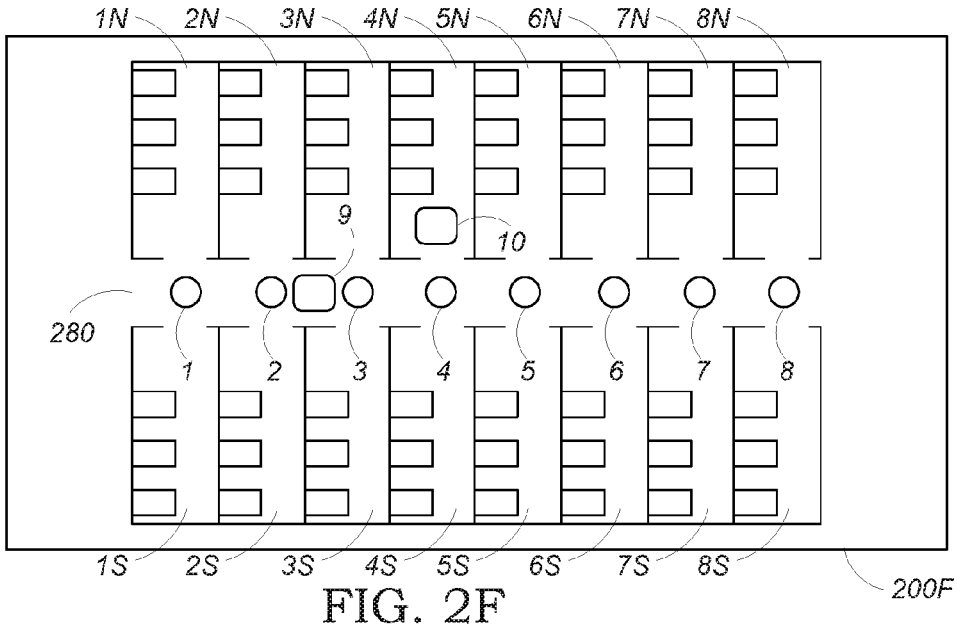


FIG. 2F

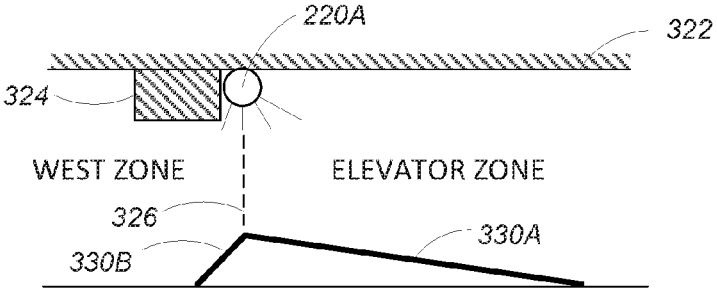


FIG. 3

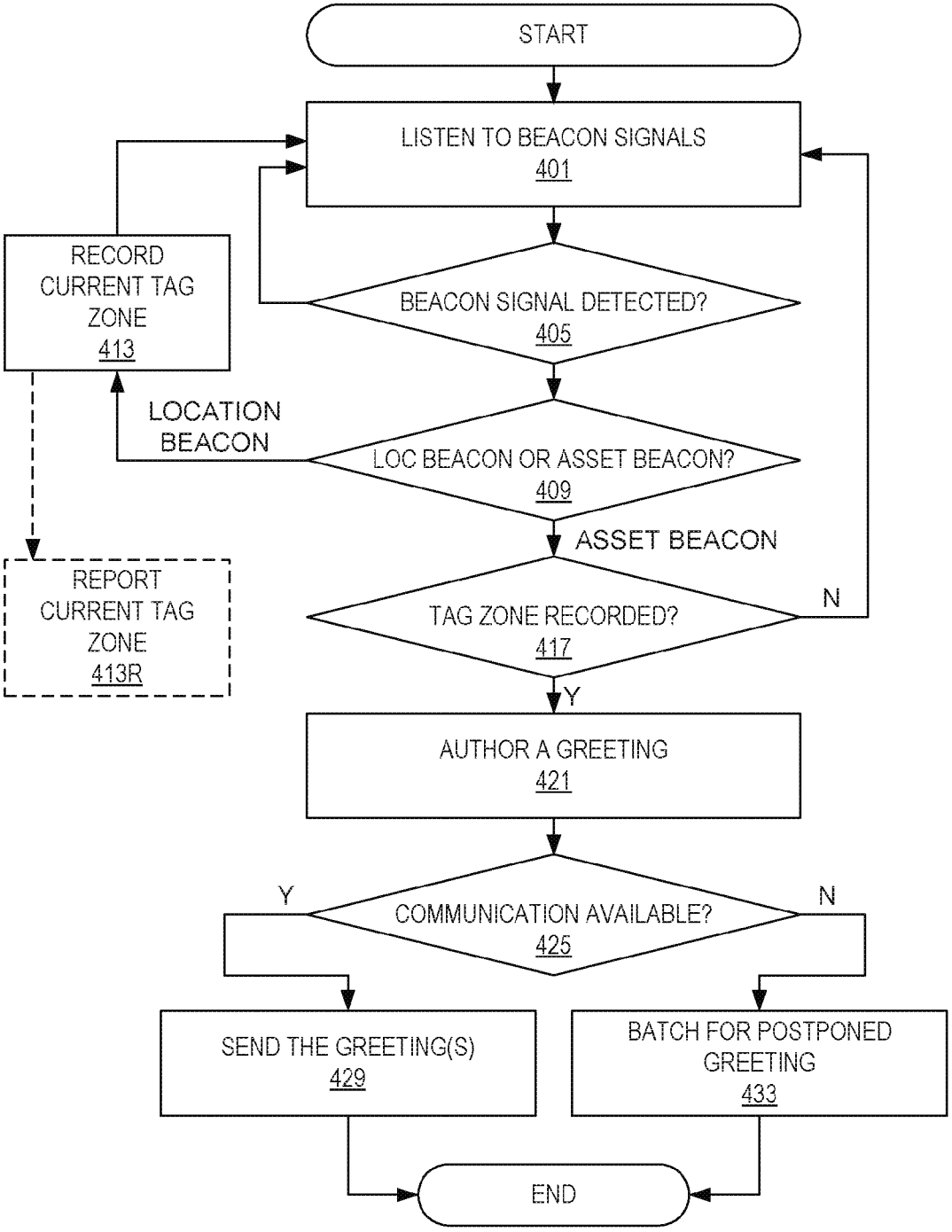

START
LISTEN TO BEACON SIGNALS
401
BEACON SIGNAL DETECTED?
405
RECORD CURRENT TAG ZONE
413
LOCATION BEACON
LOC BEACON OR ASSET BEACON?
409
ASSET BEACON
REPORT CURRENT TAG ZONE
413R
TAG ZONE RECORDED?
417
N
Y
AUTHOR A GREETING
421
Y
COMMUNICATION AVAILABLE?
425
N
SEND THE GREETING(S)
429
BATCH FOR POSTPONED GREETING
433
END

FIG. 4A

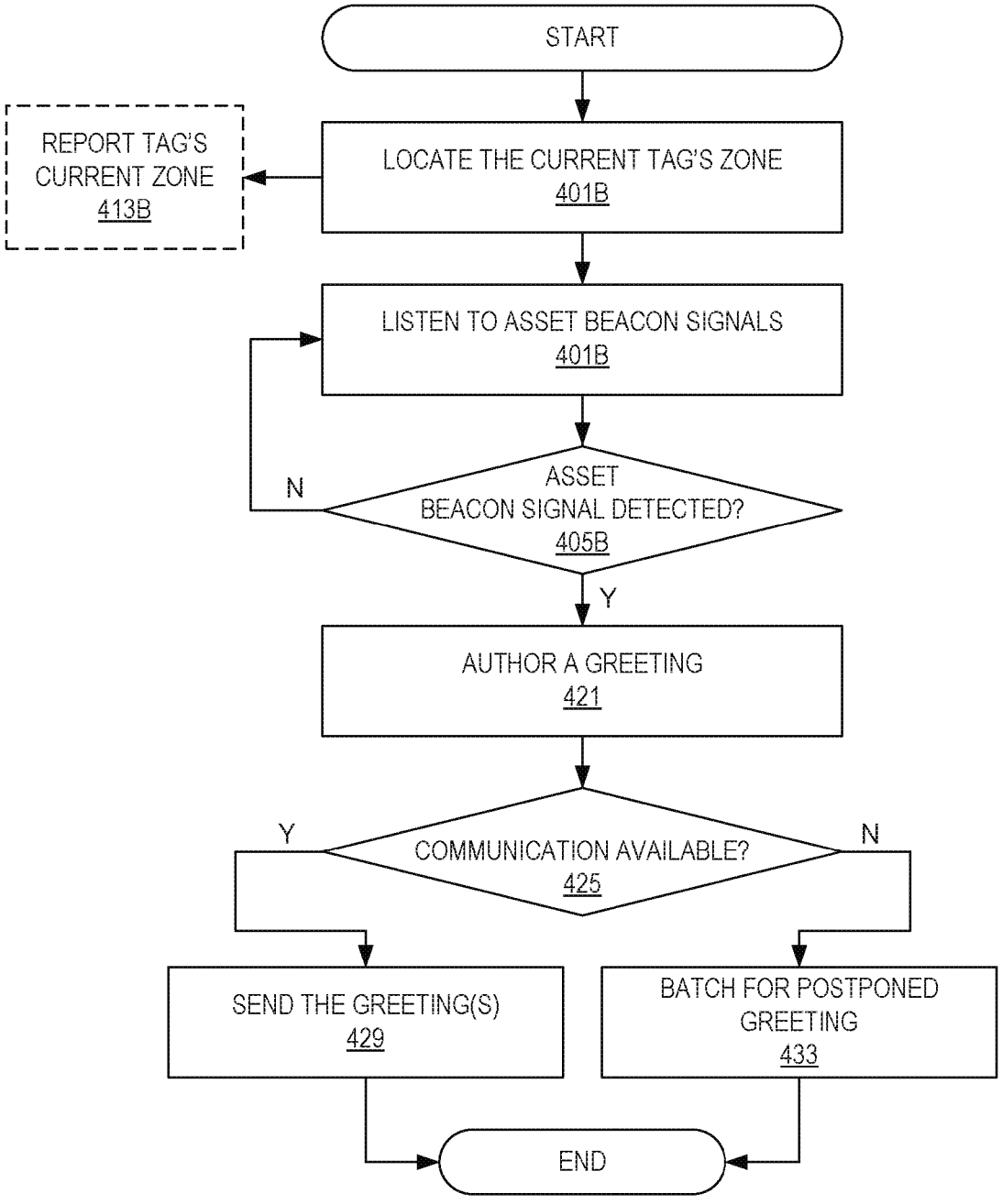

START
LOCATE THE CURRENT TAG'S ZONE
401B
REPORT TAG'S CURRENT ZONE
413B
LISTEN TO ASSET BEACON SIGNALS
401B
ASSET BEACON SIGNAL DETECTED?
405B
N
Y
AUTHOR A GREETING
421
COMMUNICATION AVAILABLE?
425
Y
N
SEND THE GREETING(S)
429
BATCH FOR POSTPONED GREETING
433
END

FIG. 4B

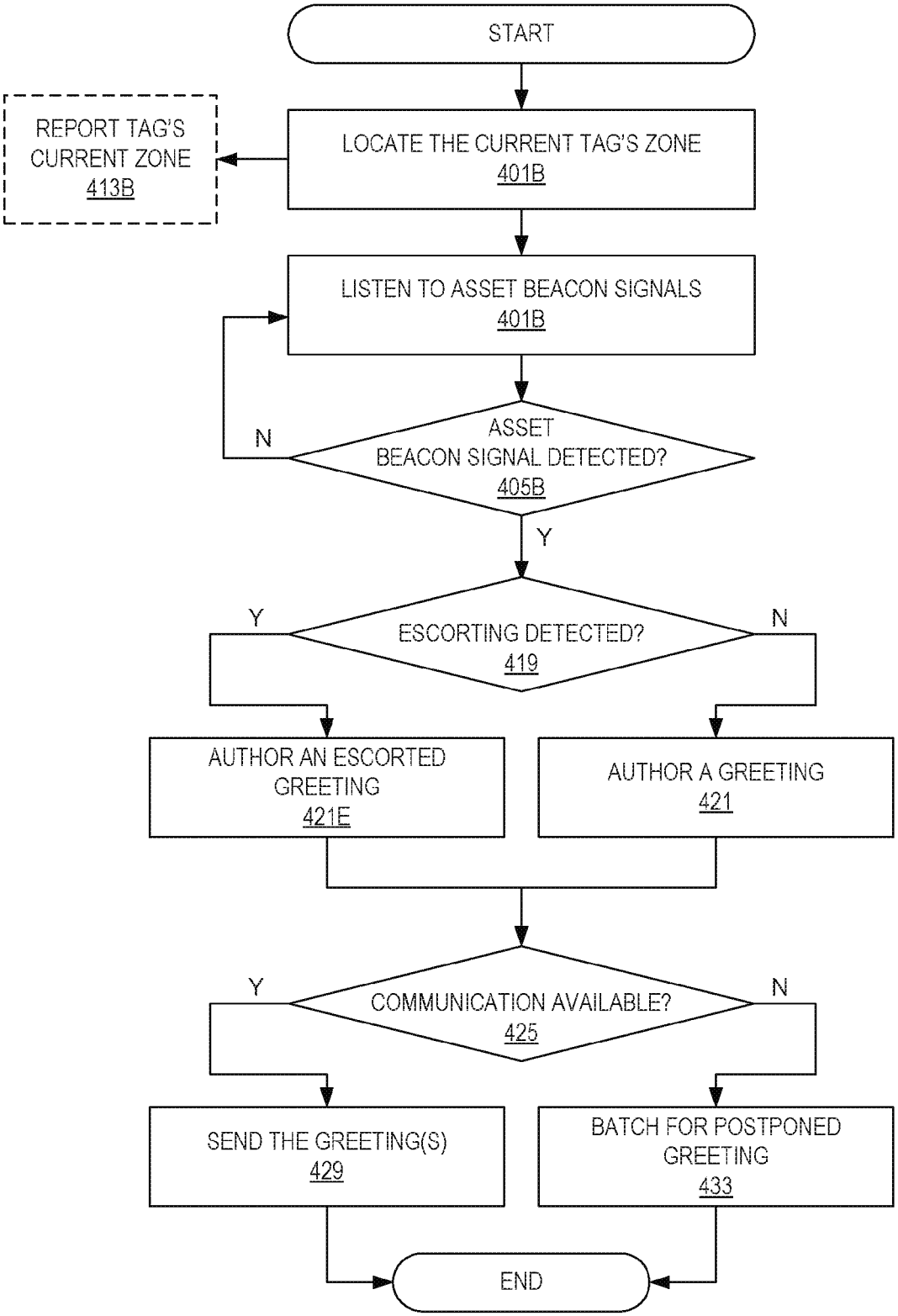

START
LOCATE THE CURRENT TAG'S ZONE
401B
REPORT TAG'S CURRENT ZONE
413B
LISTEN TO ASSET BEACON SIGNALS
401B
ASSET BEACON SIGNAL DETECTED?
405B
N
Y
ESCORTING DETECTED?
419
Y
N
AUTHOR AN ESCORTED GREETING
421E
AUTHOR A GREETING
421
COMMUNICATION AVAILABLE?
425
Y
N
SEND THE GREETING(S)
429
BATCH FOR POSTPONED GREETING
433
END

FIG. 4C

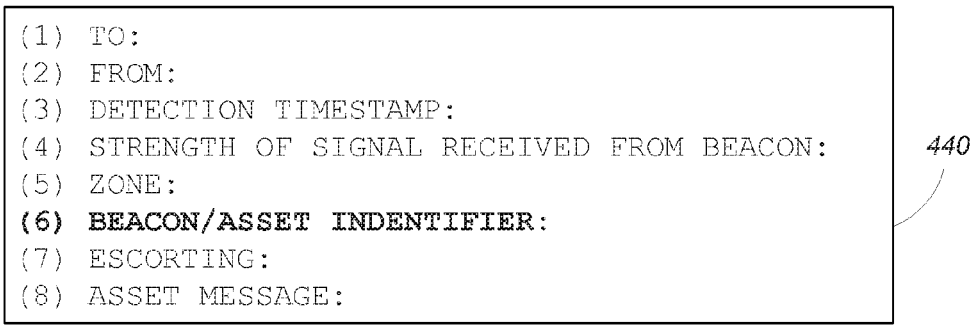

(1) TO:
(2) FROM:
(3) DETECTION TIMESTAMP:
(4) STRENGTH OF SIGNAL RECEIVED FROM BEACON:
(5) ZONE:
(6) BEACON/ASSET INDENTIFIER:
(7) ESCORTING:
(8) ASSET MESSAGE:
440

FIG. 4D

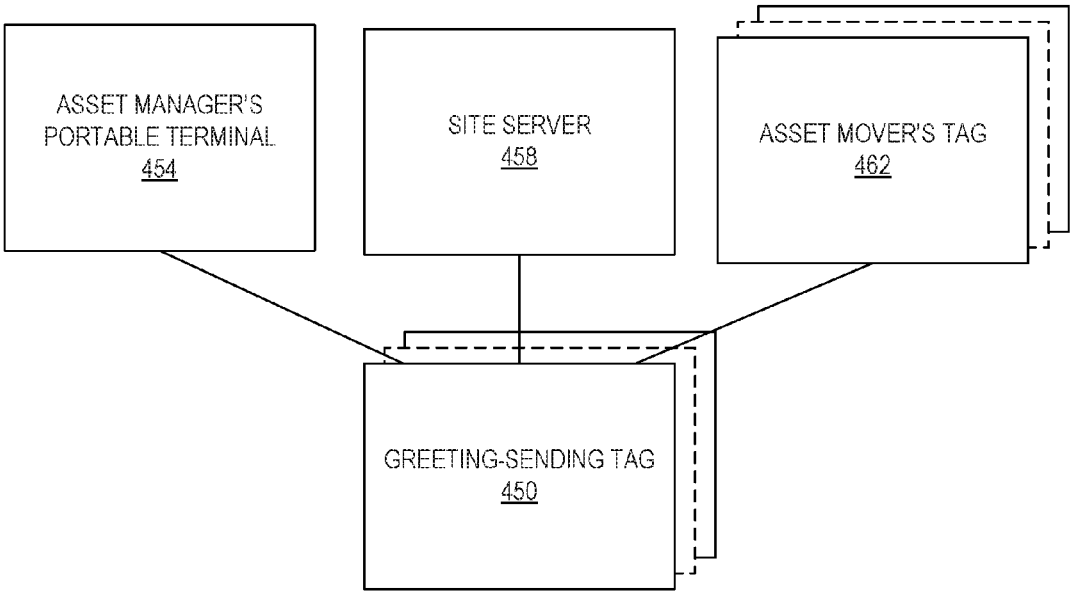

ASSET MANAGER'S PORTABLE TERMINAL 454
SITE SERVER 458
ASSET MOVER'S TAG 462
GREETING-SENDING TAG 450

FIG. 4E

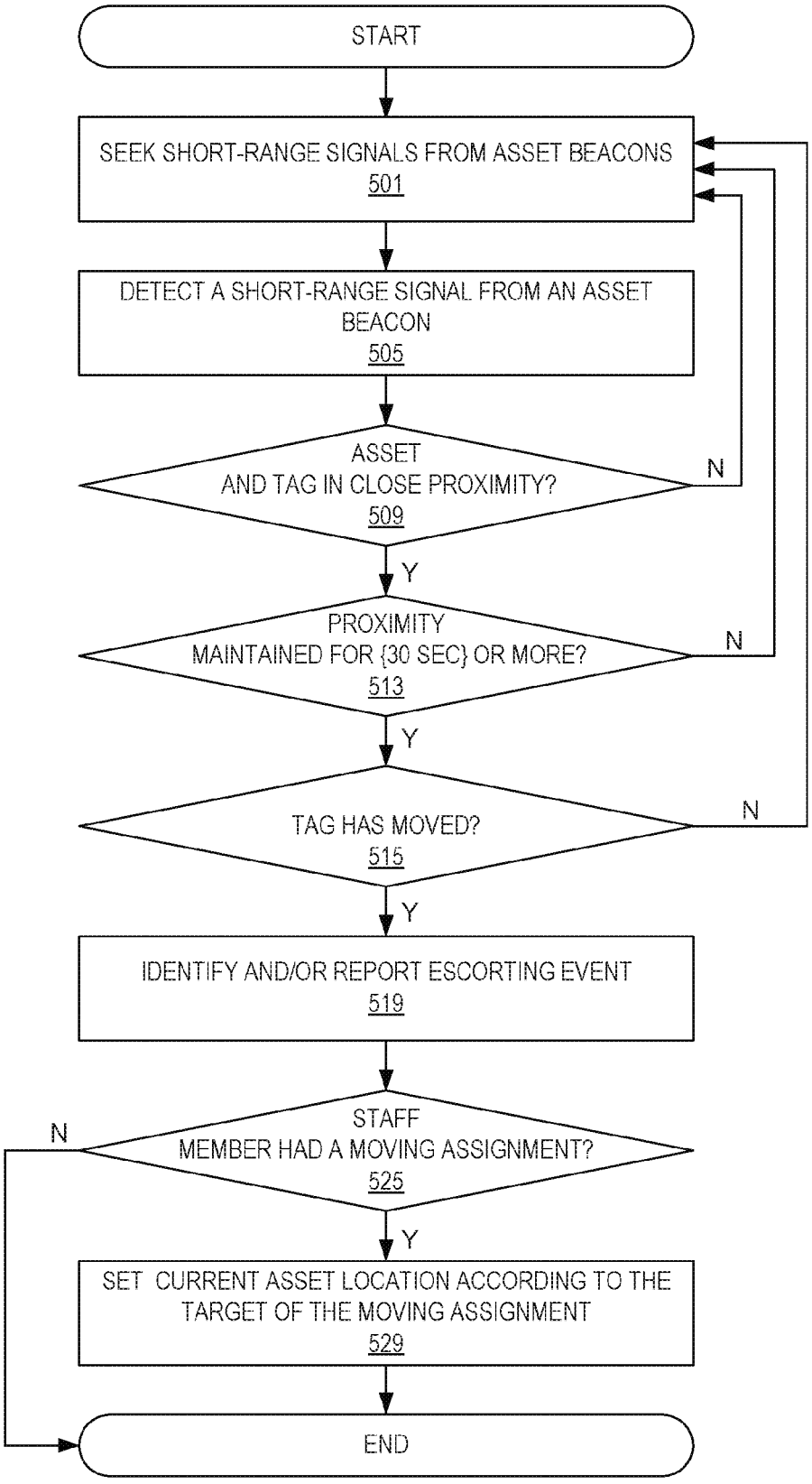

START
SEEK SHORT-RANGE SIGNALS FROM ASSET BEACONS
501
DETECT A SHORT-RANGE SIGNAL FROM AN ASSET BEACON
505
ASSET AND TAG IN CLOSE PROXIMITY?
509
N
Y
PROXIMITY MAINTAINED FOR {30 SEC} OR MORE?
513
N
Y
TAG HAS MOVED?
515
N
Y
IDENTIFY AND/OR REPORT ESCORTING EVENT
519
STAFF MEMBER HAD A MOVING ASSIGNMENT?
525
N
Y
SET CURRENT ASSET LOCATION ACCORDING TO THE TARGET OF THE MOVING ASSIGNMENT
529
END

FIG. 5

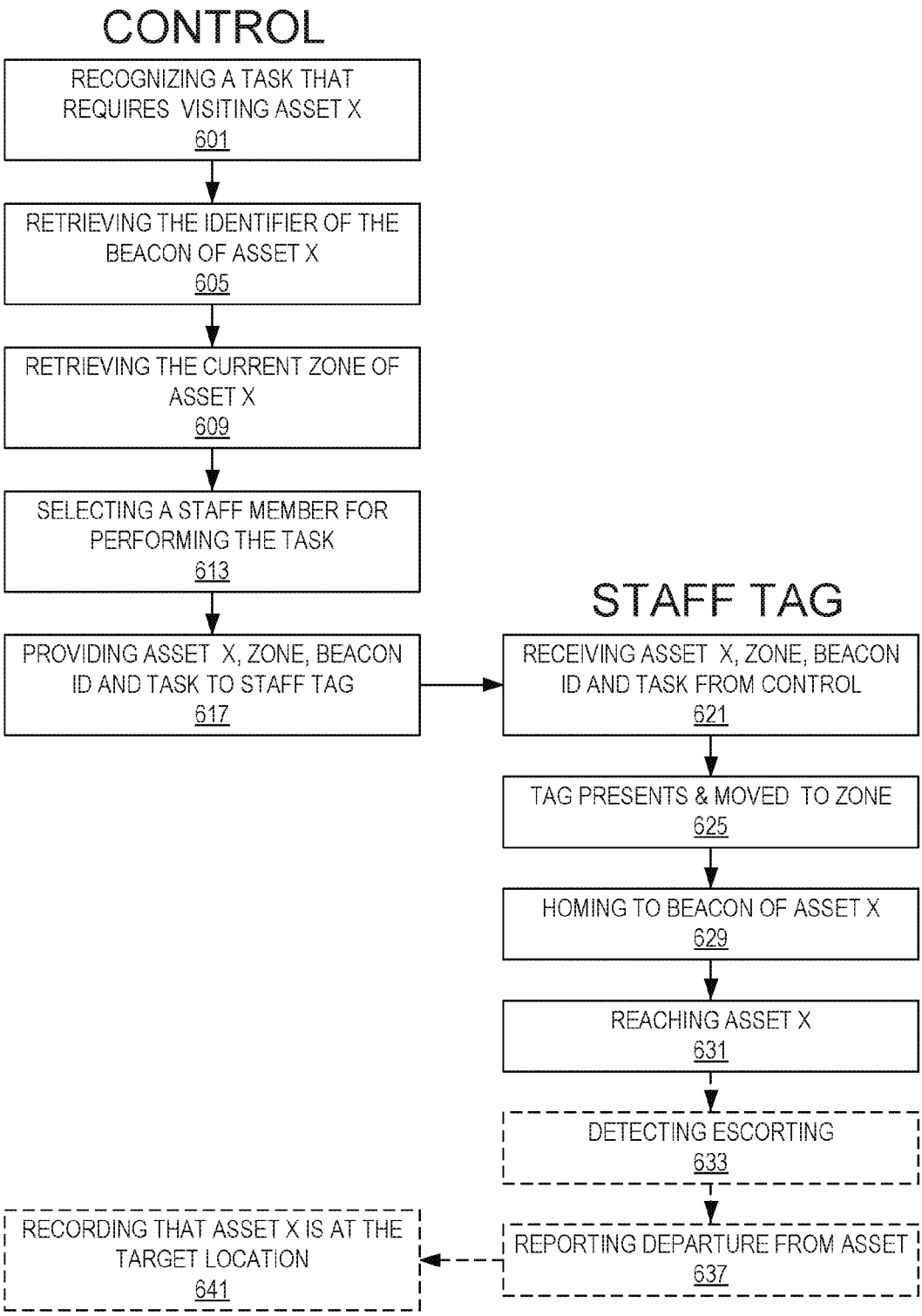

CONTROL
RECOGNIZING A TASK THAT REQUIRES VISITING ASSET X
601
RETRIEVING THE IDENTIFIER OF THE BEACON OF ASSET X
605
RETRIEVING THE CURRENT ZONE OF ASSET X
609
SELECTING A STAFF MEMBER FOR PERFORMING THE TASK
613
PROVIDING ASSET X, ZONE, BEACON ID AND TASK TO STAFF TAG
617
STAFF TAG
RECEIVING ASSET X, ZONE, BEACON ID AND TASK FROM CONTROL
621
TAG PRESENTS & MOVED TO ZONE
625
HOMING TO BEACON OF ASSET X
629
REACHING ASSET X
631
DETECTING ESCORTING
633
REPORTING DEPARTURE FROM ASSET
637
RECORDING THAT ASSET X IS AT THE TARGET LOCATION
641

FIG. 6

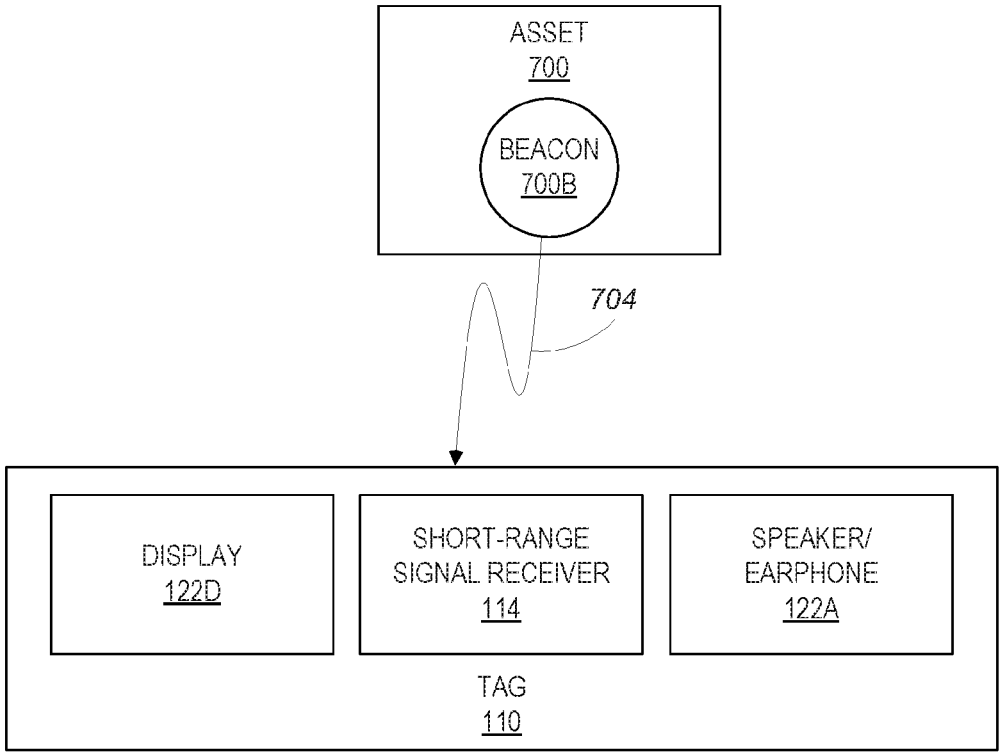


FIG. 7A

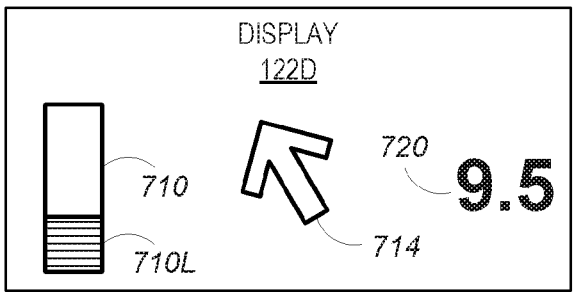


FIG. 7B

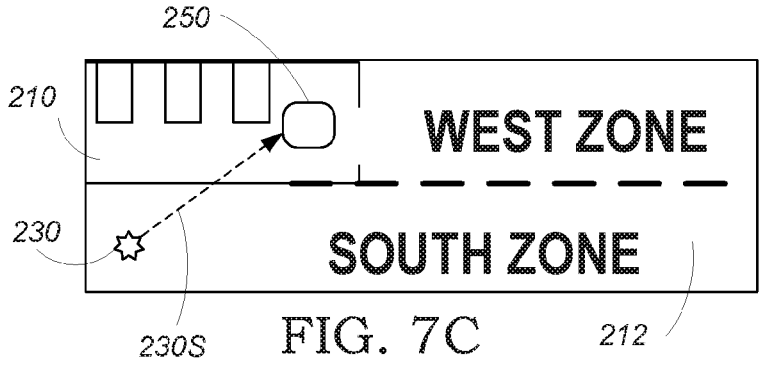


FIG. 7C

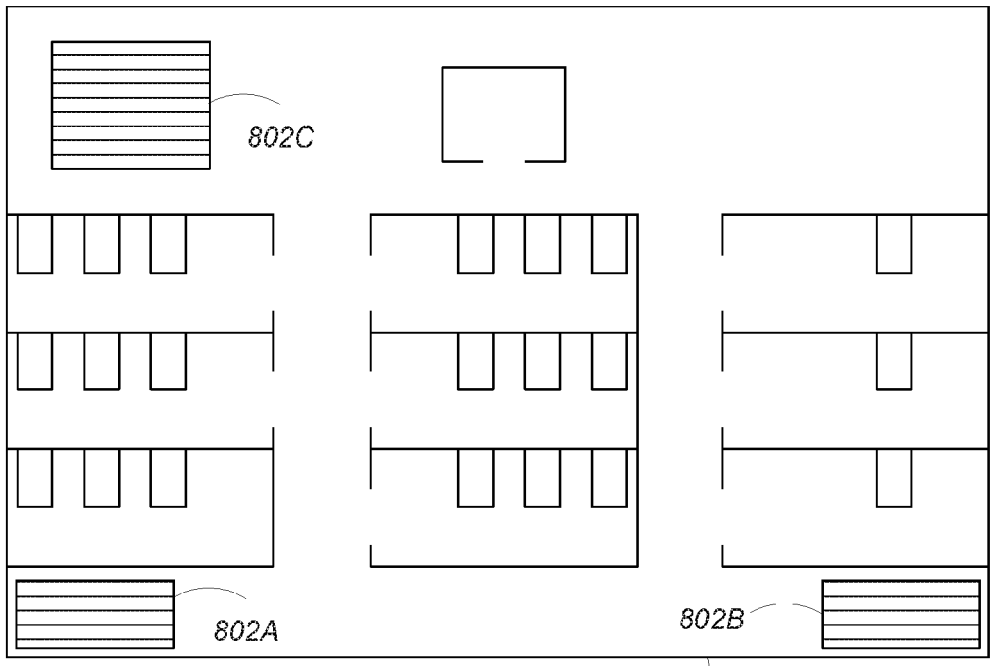

802C
802A
802B
800A

FIG. 8A

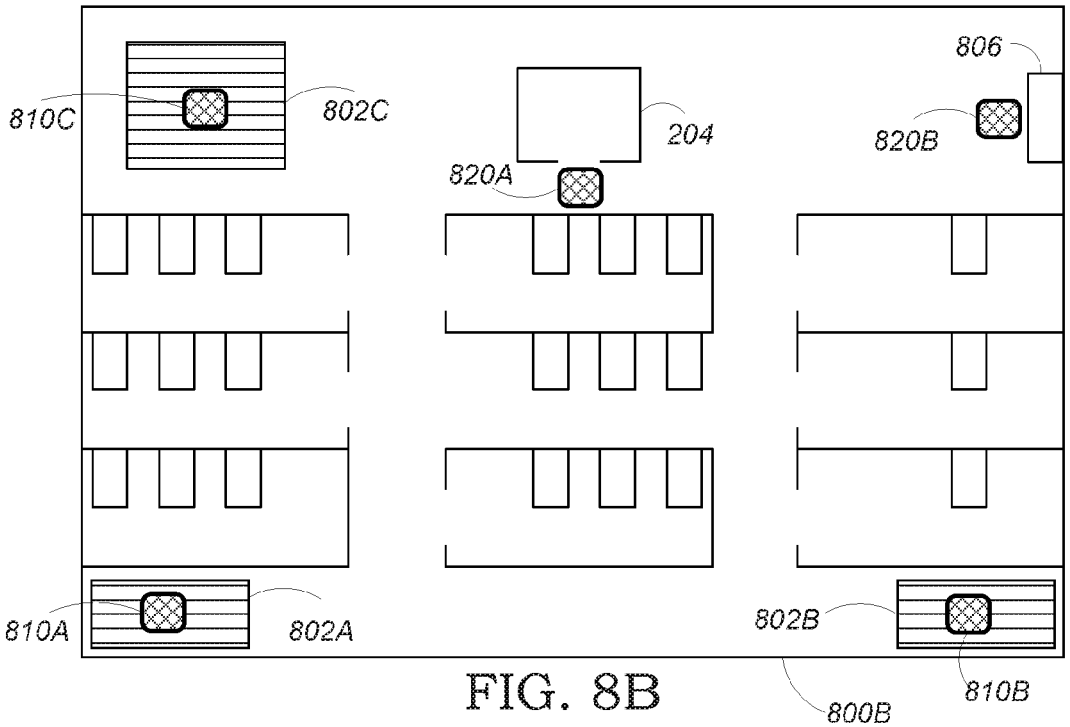

806
810C
802C
204
820B
820A
810A
802A
802B
810B
800B

FIG. 8B

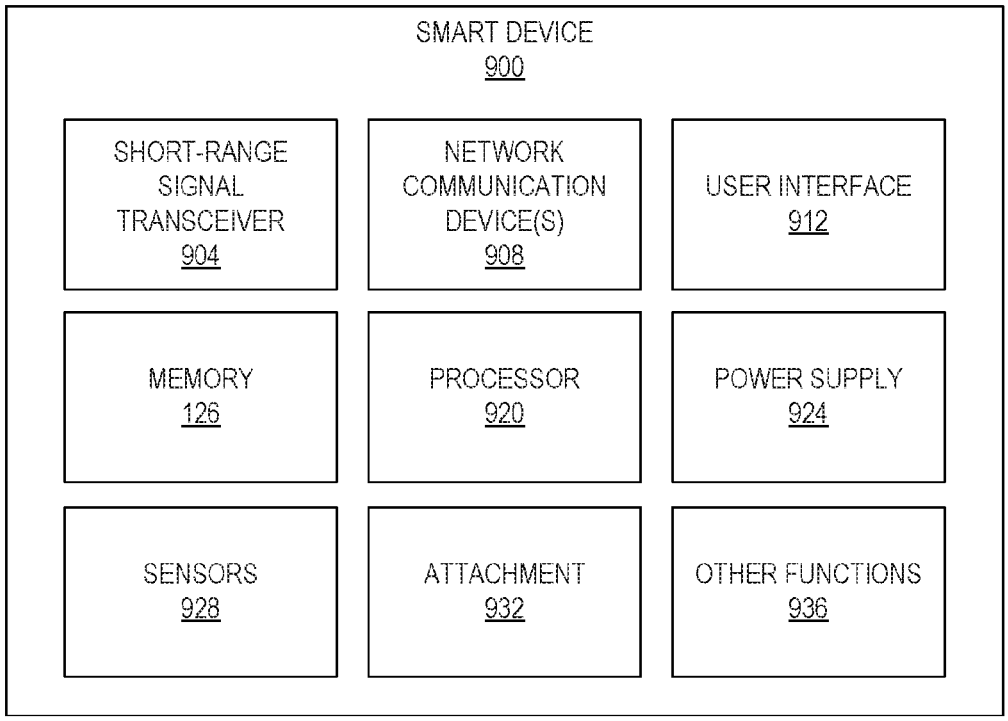

SMART DEVICE
900
SHORT-RANGE SIGNAL TRANSCEIVER
904
NETWORK COMMUNICATION DEVICE(S)
908
USER INTERFACE
912
MEMORY
126
PROCESSOR
920
POWER SUPPLY
924
SENSORS
928
ATTACHMENT
932
OTHER FUNCTIONS
936

FIG. 9A

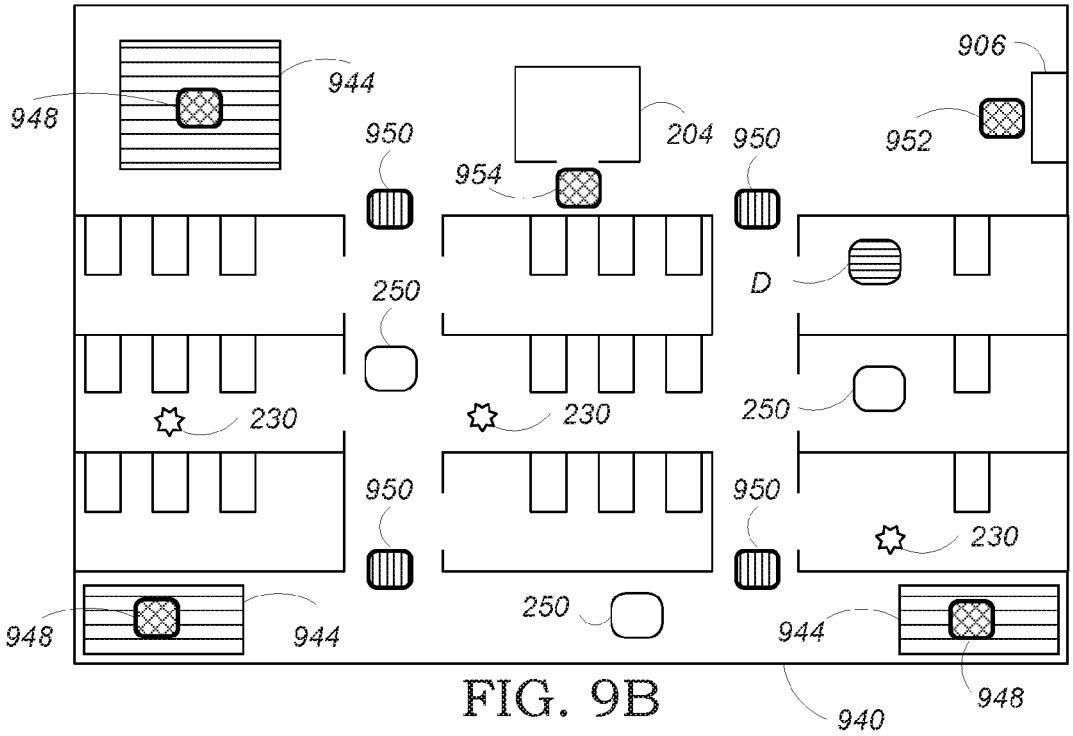

906
944
948
950
204
950
952
954
D
250
230
230
250
950
950
230
250
948
944
944
948
940

FIG. 9B

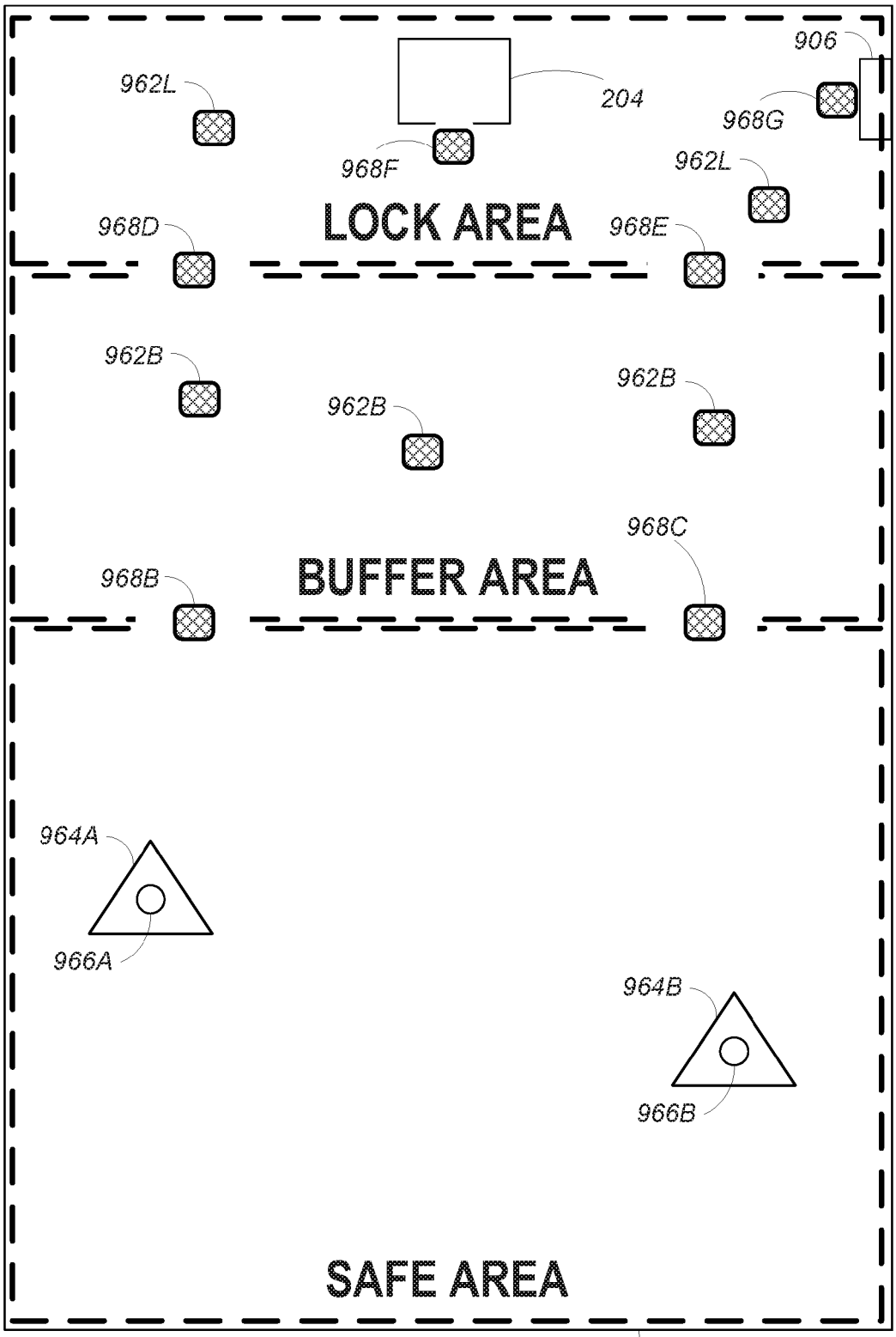

906
962L
204
968G
968F
962L
LOCK AREA
968D
968E
962B
962B
962B
968C
968B
BUFFER AREA
964A
966A
964B
966B
SAFE AREA
960

FIG. 10A

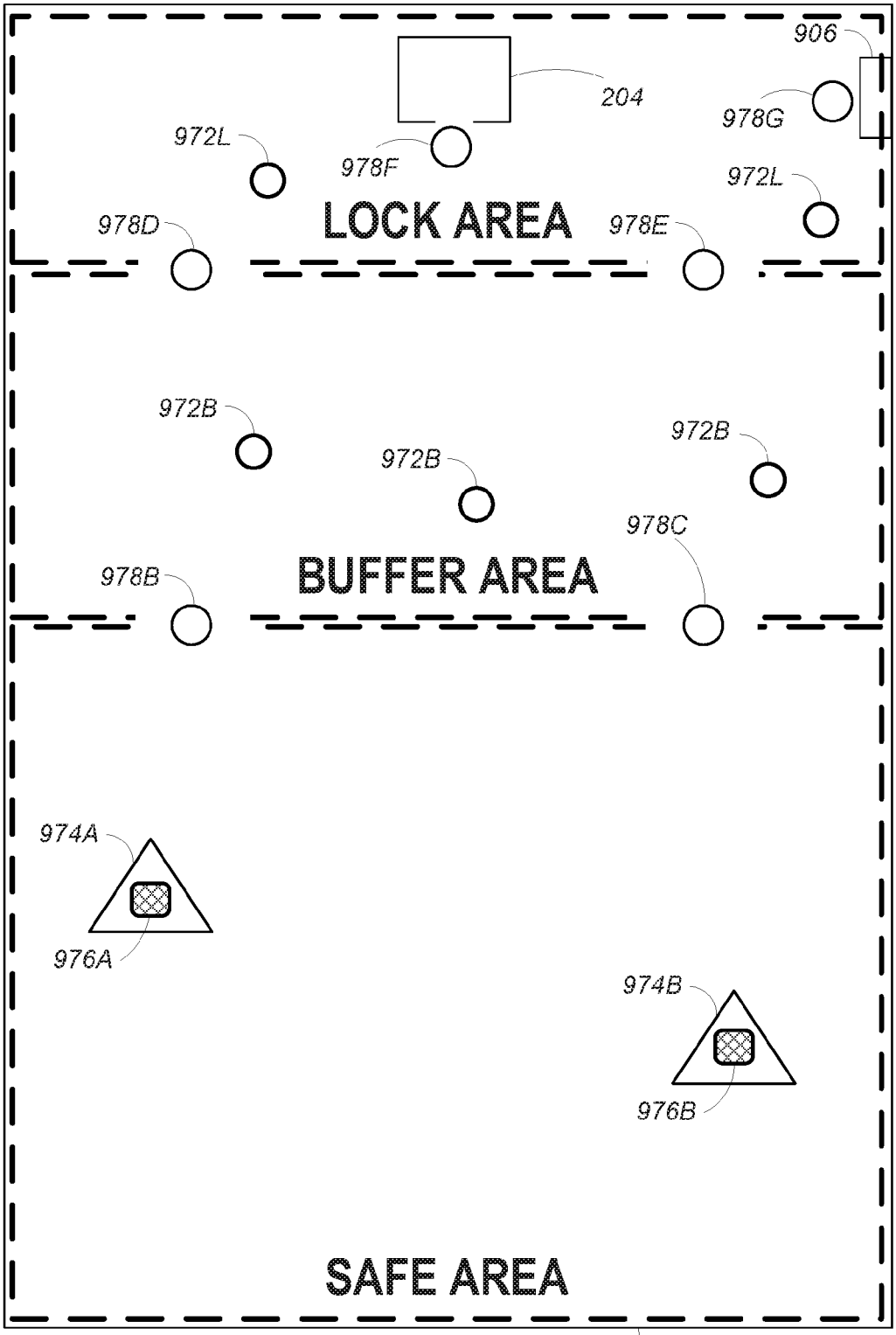

906
204
978G
972L
978F
LOCK AREA
972L
978D
978E
972B
972B
972B
978C
978B
BUFFER AREA
974A
976A
974B
976B
SAFE AREA
970

FIG. 10B

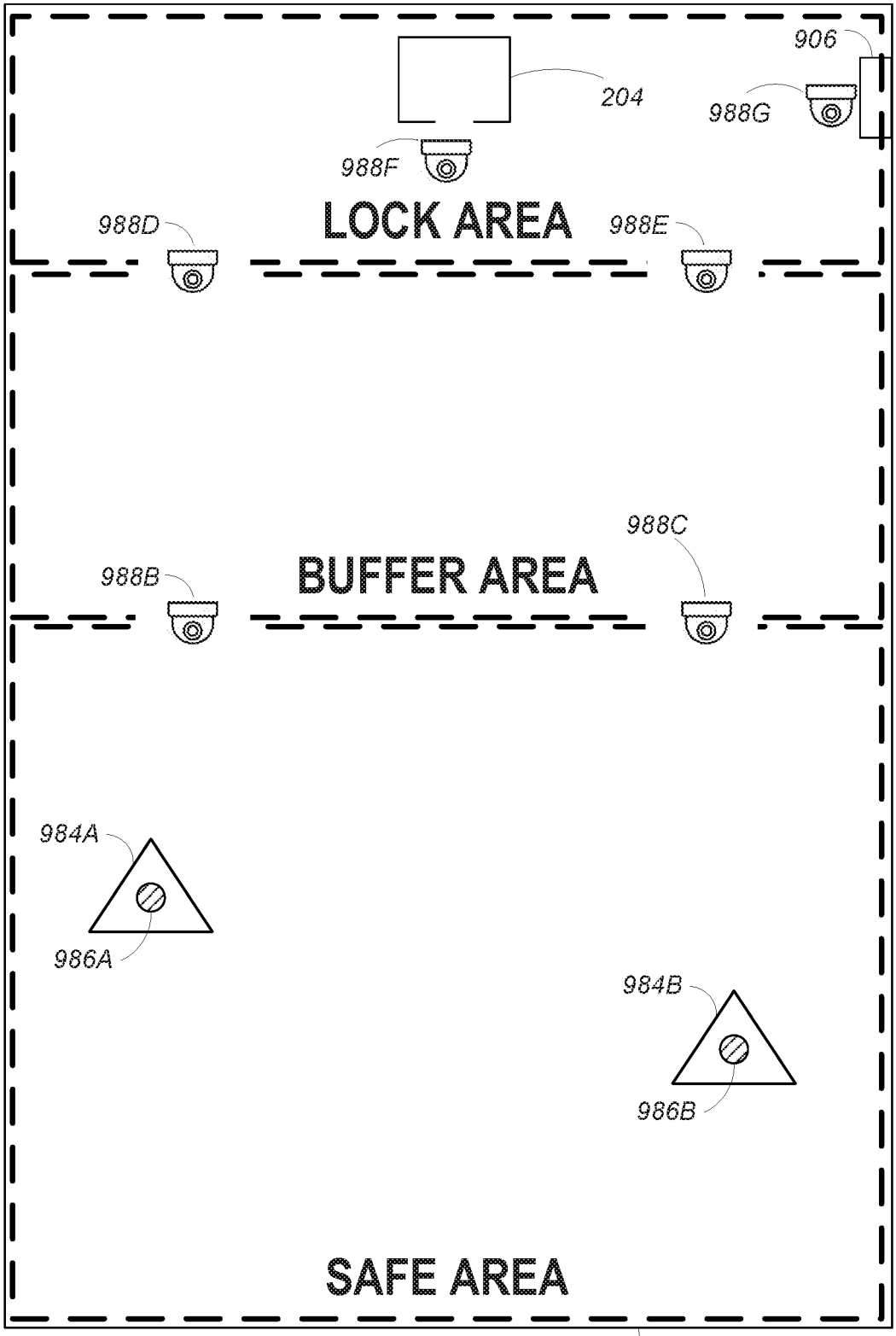

906
204
988G
988F
LOCK AREA
988D
988E
988C
988B
BUFFER AREA
984A
986A
984B
986B
SAFE AREA
980

FIG. 10C

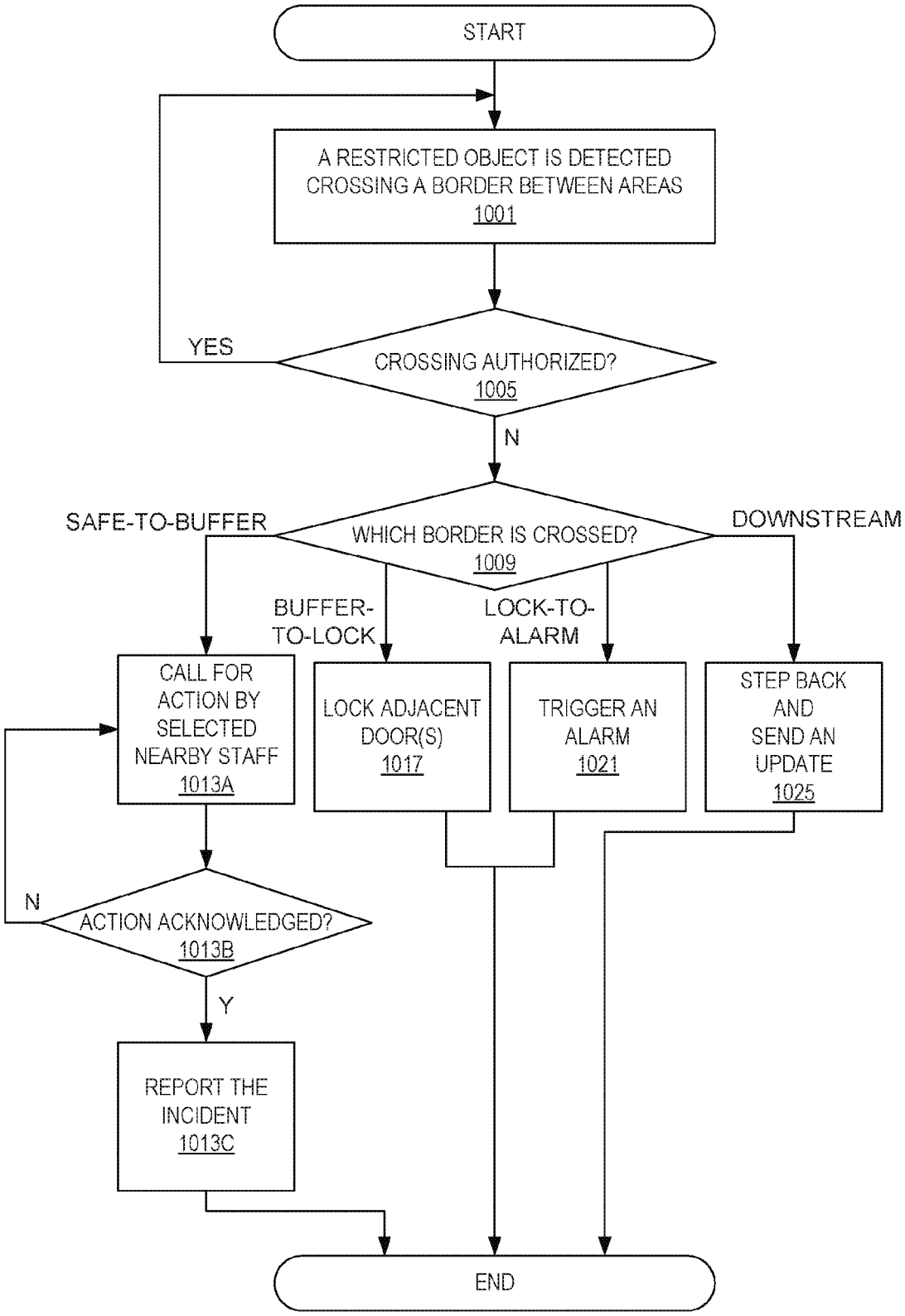

START
A RESTRICTED OBJECT IS DETECTED CROSSING A BORDER BETWEEN AREAS
1001
CROSSING AUTHORIZED?
1005
YES
N
WHICH BORDER IS CROSSED?
1009
SAFE-TO-BUFFER
BUFFER-TO-LOCK
LOCK-TO-ALARM
DOWNSTREAM
CALL FOR ACTION BY SELECTED NEARBY STAFF
1013A
LOCK ADJACENT DOOR(S)
1017
TRIGGER AN ALARM
1021
STEP BACK AND SEND AN UPDATE
1025
ACTION ACKNOWLEDGED?
1013B
N
Y
REPORT THE INCIDENT
1013C
END

FIG. 11A

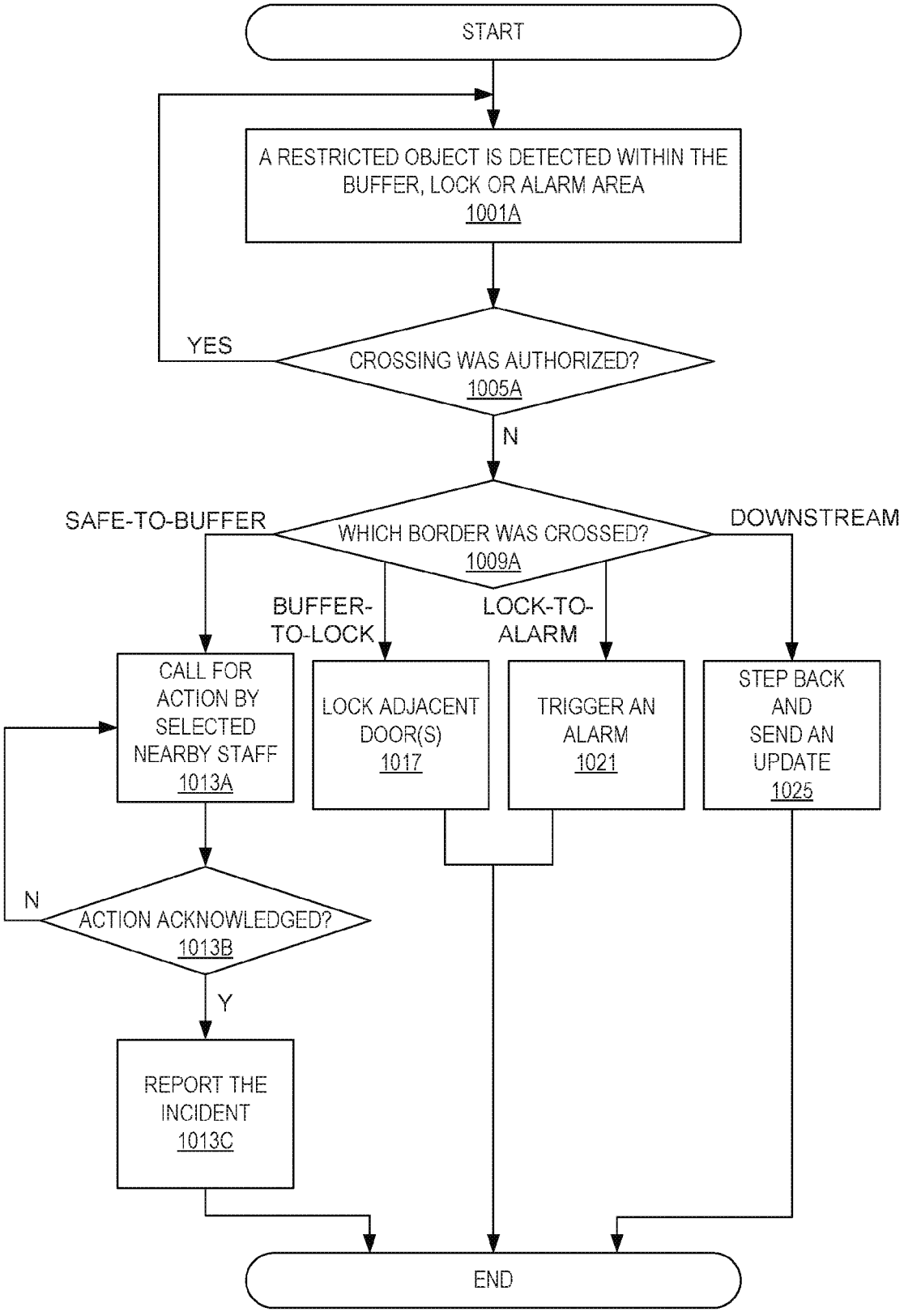

START
A RESTRICTED OBJECT IS DETECTED WITHIN THE BUFFER, LOCK OR ALARM AREA
1001A
YES
CROSSING WAS AUTHORIZED?
1005A
N
SAFE-TO-BUFFER
WHICH BORDER WAS CROSSED?
1009A
DOWNSTREAM
BUFFER-TO-LOCK
LOCK-TO-ALARM
CALL FOR ACTION BY SELECTED NEARBY STAFF
1013A
LOCK ADJACENT DOOR(S)
1017
TRIGGER AN ALARM
1021
STEP BACK AND SEND AN UPDATE
1025
N
ACTION ACKNOWLEDGED?
1013B
Y
REPORT THE INCIDENT
1013C
END

FIG. 11B

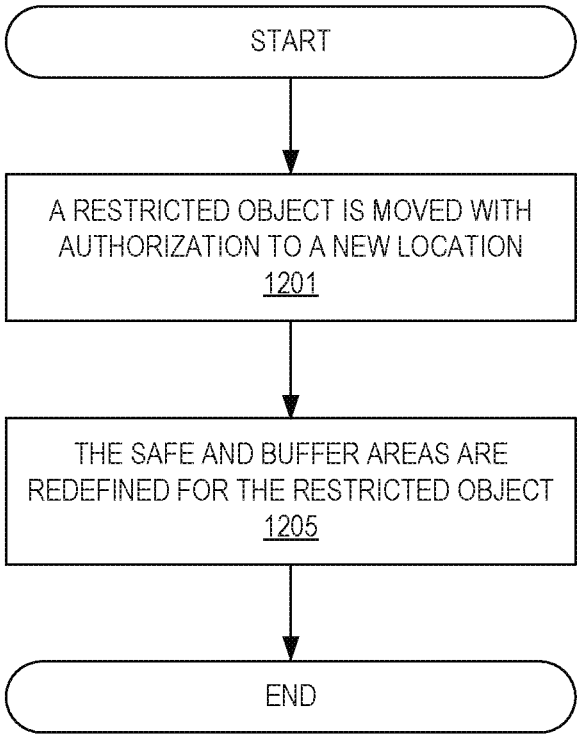

START
A RESTRICTED OBJECT IS MOVED WITH AUTHORIZATION TO A NEW LOCATION
1201
THE SAFE AND BUFFER AREAS ARE REDEFINED FOR THE RESTRICTED OBJECT
1205
END

FIG. 12

SYSTEM AND METHOD FOR LOCATING OBJECTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. patent application Ser. No. 15/211,201 filed Jul. 15, 2016 which claims the benefit of U.S. Provisional Patent Application No. 62/214,936 filed on 5 Sep. 2015; and is related to U.S. patent application Ser. No. 15/211,232 filed Jul. 15, 2016 by the present inventor titled SYSTEM AND METHOD FOR MULTI-LEVEL BORDER CONTROL WITHIN SITES, the contents of each of the above applications being incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] Field of the Invention

[0003] The present invention relates to locating objects, and in particular to locating assets and people within institutional sites.

[0004] Description of Related Art

[0005] RTLS (real time location services) systems are commonly used to locate objects, such as assets or people, within institutional sites such as manufacturing plants, warehouses, healthcare facilities or retail stores.

[0006] A typical RTLS system includes an infrastructure of fixed active devices, each located at a known location, and movable active devices, each associated with a known object. The fixed and movable active devices are adapted to establish short-range communication via an ultrasonic, infrared or low-power RF signal, and at least one of the fixed or movable active devices connects via a network to report meetings between respective active devices. Each meeting report indicates that the current location of the object associated with the movable active device is in proximity to the known location of the fixed active device, thereby providing real time location information related to the respective object.

[0007] The resolution of the detected location can be improved in a variety of ways, such as: a shorter communication range and higher number of fixed active devices; analyzing the signal strength, sometimes is association with the battery level, for estimating the current distance between the reported devices; or using triangulation for analyzing a plurality of simultaneous short-range signals associated with a single movable active device and a plurality of fixed active devices.

[0008] A typical RTLS system requires substantial investment in sensing and communication infrastructures throughout the site. While some sites justify such investment by effectively and quickly locating critical equipment or personnel, and others show high returns from targeted advertising, there are still many other sites that could benefit from quickly locating objects, and cannot afford or justify the expense associated with deploying the respective sensing and communication infrastructure of a common RTLS system.

[0009] The present disclosure comes to teach locating systems with highly reduced sensing and communication infrastructures, and some applications of such systems.

BRIEF SUMMARY OF THE INVENTION

Definitions

[0010] An "institutional site", abbreviated "site", is a managed place that is run by a "staff". Examples of sites include manufacturing plants, warehouses, healthcare facilities or retail stores. A "staff member" is an employee or volunteer operating in a site. A "mover" is a staff member designated to move an asset to a specified target location. Being a mover may be the main job of a staff member, or an occasional incident. A site may accommodate additional persons that are not staff members, such as residents, customers or visitors.

[0011] An "asset" is a thing that may be needed for a useful purpose. People are not considered herein assets, and the term "object" will be used herein to refer to both people and assets that need to be located. An "asset identifier", such as an inventory number, uniquely identifies an asset within a site. An asset identifier may also include a human-comprehensible "asset description" to describe an asset to staff members; examples for asset descriptions are the respiratory machine, respiratory machine no. 37, or the yellow respiratory machine.

[0012] An "active device" is an electronic device capable of transmitting and/or receiving data.

[0013] A "smart tag", abbreviated "tag", is herein an active device that plays a role in locating objects and is capable of communicating location information. Smart tags include "personal tags" borne by persons, "asset tags" attached to assets, and "fixed tags" that are fixed at a location. In a healthcare facility, personal tags include "staff tags" and "resident tags" borne by staff members and residents, respectively, or may further include "visitor tags" borne by visitors. A tag is preferably configured according to the respective role and identity of the person, asset or location associated with the tag. A personal tag may be a dedicated device assigned to a person, or a private communication device of a person, such as a smartphone, programmed to function as a tag.

[0014] A "beacon" is an active device recurrently transmitting a short-range signal for being received and read by tags that are within a short maximum range, the preferred maximum range being between a meter and a few tens of meters, depending on the application. A "location beacon" is fixed to a specific location within a site, such as on a wall or a ceiling; an "asset beacon" is attached to an asset and moves with the asset; while a "personal beacon" is borne by and moves with a person. The term "attached to an asset" covers also the case where the beacon forms an integral part of the asset. As long as a certain object beacon is known to be borne by or attached to a certain object, expressions such as "detecting an object", "detecting an object beacon"; "locating an object", "locating an object beacon"; "receiving a signal from an object", or "receiving a signal from an object beacon"; may be used interchangeably. The short-range signal transmitted by the beacon preferably uses low-power RF, ultrasound or infrared to carry the "beacon identifier" uniquely identifying the beacon within the site, and possibly also information regarding the battery level of the beacon, and/or object status information received by the beacon from an object by which the beacon is borne or to which the beacon is attached. A beacon short-range signal is read by a compatible receiver that forms part of a tag or another signal detecting device, to identify the beacon and possibly also

identify the object by whom the beacon is borne to which the beacon is attached, as well as to optionally receive other information carried by the signal. A receiver may also measure the strength of the short-range signal received from a beacon, which may be indicative of the current distance between the receiver and the beacon, which is similar to the distance between the tag and the object. iBeacon, marketed by numerous vendors in compliance with a standard published by Apple, Cupertino, Calif., is an example of a beacon that uses BLE (Bluetooth low energy) for its short-range signal, while a variety of contemporary smartphones can be programmed to act as compatible receivers.

[0015] A "visual feature" is a distinguishable visual mark, symbol, pattern, image or color that can be captured by a camera and processed by an image processor to identify a location, an object or an object type. Visual features may be invisible to the naked eye, for example by using ink in the infrared wavelength, as long as the respective cameras can see them and use appropriate filters, if needed. In the present context, visual features may be borne by objects or fixed to locations, and function similarly to beacons, if respective tags are adapted to detect and recognize them.

[0016] "Bearing" a tag, a beacon or a visual feature by an object will generally relate to a person carrying or wearing a tag, a beacon or a visual feature, or an asset having a tag, a beacon or a visual feature attached thereto or embedded therein.

[0017] It shall be appreciated that some active devices may function as both tags and beacons. Thus, a tag may locate another tag via short-range communication.

[0018] Databases that are stored in or are accessible by tags may correlate object identifiers with beacon identifiers and object descriptions, and it is presumed herein that providing an object identifier to a tag makes the corresponding beacon identifiers and/or asset descriptions readily available to the tag.

[0019] "Locating" an object means obtaining information pertaining to the current location of the object, while "directing" toward an object means providing human-comprehensible directions to a person for reaching the object according to its location.

SUMMARY

[0020] The following discussion mostly uses examples pertaining to healthcare facilities. However, it shall be appreciated that the teachings of the present disclosure relate to a variety of other institutional sites as well.

[0021] The present disclosure recognizes that, under certain circumstances, a locating and directing system can be highly simplified by realizing, and making use of the fact, that assets are usually moved by staff members; that staff members are often intelligent, experienced persons who are familiar with the assets and the site and typical locations where assets are used or parked, and have eyes; and that staff members often accidently pass by assets in the course of performing their routine duties.

[0022] The following concepts will facilitate the understanding of the present disclosure:

[0023] "Zoning" is a division of a site into relatively large zones, serving for roughly locating objects. The term zoning will also be used herein to denote the act of zone-level locating of an object, i.e. identifying the zone in which an object resides. It is assumed that, under certain circumstances, zoning may be good enough for effective, timely locating of objects; for example, a staff member requested to "fetch a respiratory machine from the West Zone on the 3rd floor" will often reach the machine pretty quickly, maybe just a few seconds later than when being requested, in another similar site employing a common, fully-fledged RTLS system, to "fetch a respiratory machine from next to bed C in room 305". Zones may partly overlap, thus zoning may afford some level of ambiguity, as will be elaborated later below.

[0024] "Homing" is a method for directing a user holding a receiver toward a target asset having an asset beacon, by seeking a short-range signal transmitted by the target asset, and when the short-range signal is detected, continuously monitoring the short-range signal for approaching the asset, for example by exhibiting a series of human-comprehensible homing directions toward the asset, based on the receiver providing to the user a series of visual and/or audio indications of the current measured strength of the signal received from the beacon, that may be presented in terms of estimated distance, which intuitively leads the user to seek stronger signals hence approach the asset. In more sophisticated systems, homing may provide explicit direction indications, such as by displaying an arrow pointing at the asset. Homing may complement zoning for fast screening of larger zones, including, for example: for finding the asset faster; for distinguishing a sought specific asset from other similar assets; for finding assets that hide behind curtains that are permeable to the beacon's short-range signal; for indicating, by an absence of a beacon signal, that the sought asset is not within a certain part of the zone; or just for verifying that the related asset is in the zone without physically approaching the asset.

[0025] "Greeting" is an asset location report message authored and sent by a tag that has detected the beacon of the asset, thereby associating the location of the asset with the zone of the tag. A greeting may be informally described as a message sent by a tag to a recipient, stating: I am currently in zone X and have just seen asset Y. In a typical healthcare facility, for example, many tags are continually passing by assets, purposely or accidently, providing a continuous series of greetings that serve to dynamically locate assets, as will be further elaborated below.

[0026] "Escorting" is an event of detecting continuous close proximity between a tag and an asset beacon maintained for a prolonged duration, say thirty seconds or more, while also detecting that the tag has moved a substantial distance, say several meters or more, during the duration of the close proximity. An escorting event may be interpreted as a displacement of the respective asset by the person bearing the tag. If a staff member has been commissioned to move a certain asset to bed C in room 305, then the respective escorting event may indicate by default that at the end of the escorting event the asset is located next to bed C in room 305.

[0027] According to preferred embodiments of the present invention there is provided a method of operation of a tag for locating assets, the tag is for being borne by and occasionally moving with a user within a site that is divided into a plurality of zones, the method including: receiving a second short-range signal from an asset beacon attached to an asset; retrieving from the second short-range signal an identification of at least one of the asset beacon or the asset; wirelessly reporting the current zone to a recipient; and wirelessly reporting the identification to the recipient.

[0028] The method may further include checking the availability of a network connection, and either or both of the reporting the current zone or the reporting the identification is postponed until the network connection is available. The current zone and the identification of the asset or asset beacon may be included within a single locating message, or be reported separately, when available. It will be noted that reporting the current zone and reporting the identification of the asset beacon or the asset are preferably made automatically according to predefined rules, without requiring human initiative or action.

[0029] The method may serve a user who is a staff member bearing a staff tag that is further operative for directing the staff member toward target assets, by receiving a target asset identifier and a target zone associated with a target asset; presenting to the staff member a description of the target asset; and presenting to the staff member directions for reaching the target zone.

[0030] If the staff member is designated to relocate the target asset, the method may further include: receiving a relocation assignment identifying a target location for the target asset; detecting short-range beacon signals transmitted by a beacon of the target asset; learning from the beacon signals that the staff tag and the beacon are in close proximity; measuring the duration of the close proximity; checking whether the staff tag has moved while the close proximity is maintained; and, based on the results of the measuring and the checking: locating the target asset at the target location.

[0031] The method may also include: seeking beacon signals that match a beacon identifier of a beacon attached to the target asset; and, upon detecting a beacon signal that matches the beacon identifier: producing a series of human-comprehensible homing directions for approaching the target asset.

[0032] The directions for reaching the target zone may include a name of the target zone or instructions for reaching the target zone. The step of presenting directions may include displaying text instructions, displaying graphical guidance, or playing audio instructions. The step of producing a series of homing directions may include displaying a textual representation of a current strength of the detected beacon signal, displaying a textual guidance regarding the direction of the beacon, displaying a graphical representation of a current strength of the detected beacon signal, displaying a graphical guidance regarding the direction of the beacon, playing an audio signal that is indicative of the current strength of the detected beacon signal, or playing an audio guidance regarding the direction of the beacon.

[0033] Also provided is a method of operation of a tag of a person for directing the person toward target assets, the method including: receiving a target asset identifier and a zone associated with the target asset; presenting to the person a description of the target asset; presenting to the person directions for reaching the zone; seeking beacon signals that match a beacon identifier of a beacon attached to the target asset; and upon detecting a beacon signal that matches the beacon identifier: producing a series of human-comprehensible homing directions for approaching the asset. If the person is a staff member designated to relocate the target asset, the method may further include: receiving a relocation assignment identifying a target location for the target asset; detecting short-range beacon signals transmitted by a beacon of the target asset; learning from the beacon signals that the staff tag and the beacon have reached close proximity; measuring the duration of the close proximity; checking whether the staff tag has moved while the close proximity has been maintained; and based on the results of the measuring and the checking: locating the target asset at the target location.

[0034] Also provided is a tag for locating assets, the tag is for being borne by and occasionally moving with a user within a site that is divided into a plurality of zones, the tag including: a short-range signal receiver; a network communication device; and a processor controlling the short-range signal receiver and the network communication device, the processor is programmed to: receive a first short-range signal from a location beacon associated with a current zone of the plurality of zones, receive a second short-range signal from an asset beacon attached to an asset, retrieve from the second short-range signal an identification of at least one of the asset beacon or the asset, wirelessly report the current zone to a recipient, and wirelessly report the identification to the recipient.

[0035] The processor of the tag may be further programmed to check the availability of a network connection, and at least one of the report the current zone or the report the identification is postponed until the check is positive. The processor may include both reporting the current zone and reporting the identification within a single locating message, or report them separately, when available.

[0036] If the user is a staff member bearing a staff tag that has a user interface for directing the staff member toward target assets, the processor of the tag may be further programmed to: receive a target asset identifier and a target zone associated with a target asset, present to the staff member a description of the target asset, and present to the staff member directions for reaching the target zone.

[0037] If the user is a staff member bearing a staff tag, and the staff member is designated to relocate the target asset, the processor is further programmed to cooperate with the short-range signal receiver and the network communication device to: receive a relocation assignment identifying a target location for the target asset; detect short-range beacon signals transmitted by a beacon of the target asset; learn from the beacon signals that the staff tag and the beacon have reached close proximity; measure the duration of the close proximity; check whether the staff tag has moved while the close proximity has been maintained; and, based on the results of the measure and the check: locate the target asset at the target location.

[0038] The processor of the tag may be programmed to cooperate with the short-range signal receiver to: seek beacon signals that match a beacon identifier of a beacon attached to a target asset; and upon detecting a beacon signal that matches the beacon identifier: produce a series of human-comprehensible homing directions for approaching the target asset.

[0039] Also provided is a tag of a person for directing the person toward target assets, the tag including: a short-range signal receiver; a network communication device; a user interface; and a processor controlling the short-range signal receiver, the network communication device and the user interface. The processor is programmed to: receive via the network communication device a target asset identifier and a zone associated with the target asset; present to the person via the user interface a description of the target asset; present to the person via the user interface directions for reaching

the zone; seek via the short-range signal receiver beacon signals that match a beacon identifier of a beacon attached to the target asset; and upon detecting a beacon signal that matches the beacon identifier: produce via the user interface a series of human-comprehensible homing directions for approaching the asset. If the person is a staff member designated to relocate the target asset, the processor may be further programmed to: receive via the network communication device a relocation assignment identifying a target location for the target asset; detect via the short-range signal receiver short-range beacon signals transmitted by a beacon of the target asset; learn from the beacon signals that the staff tag and the beacon have reached close proximity; measure the duration of the close proximity; check whether the staff tag has moved while the close proximity has been maintained; and, based on the results of the measuring and the checking: locate the target asset at the target location.

[0040] It will be noted that when locating objects is described as based on analyzing short-range communication between a fixed active device and a moving active device, additional fixed active devices may concurrently communicate with the same moving active device, for increasing location measurement resolution and accuracy, for example by triangulation. Such locating techniques are well-known in the art, and may be selectively implemented in the appropriate cases, even if they are not explicitly described.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0041] The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

[0042] FIGS. **1**A-**1**B are block diagrams describing systems according to preferred embodiments of the present invention.

[0043] FIGS. **2**A-**2**F are schematic illustrations of floor layouts of preferred embodiments of the present invention.

[0044] FIG. **3** is a schematic illustration depicting asymmetry purposely included in a zone border beacon according to a preferred embodiment of the present invention.

[0045] FIGS. **4**A-**4**C are flowcharts describing asset locating processes according to preferred embodiments of the present invention.

[0046] FIG. **4**D is a schematic illustration of the contents of a greeting according to a preferred embodiment of the present invention.

[0047] FIG. **4**E is a block diagram depicting distribution of greetings according to preferred embodiments of the present invention.

[0048] FIG. **5** is a flowchart depicting the detection of escorting events according to a preferred embodiment of the present invention.

[0049] FIG. **6** is a flowchart depicting a process of directing a staff member toward an asset according to a preferred embodiment of the present invention.

[0050] FIGS. **7**A-**7**C are schematic illustrations that pertain to homing, according to preferred embodiments of the present invention.

[0051] FIGS. **8**A-**8**B are schematic illustrations that describe floor layouts that include blind areas.

[0052] FIG. **9**A is a block diagram of an enhanced smart device according to a preferred embodiment of the present invention.

[0053] FIG. **9**B is a schematic illustration that depicts a floor layout for demonstrating exemplary smart device implementations.

[0054] FIGS. **10**A-**10**C are schematic illustration of floor layouts that pertain to multi-level border security.

[0055] FIGS. **11**A, **11**B and **12** are flowcharts describing the process of operating a multi-level border control system.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

The System

[0056] FIG. **1**A is a block diagram depicting system **100**A according to a preferred embodiment. Each tag **110** of plurality of tags listens to short-range signals that may be transmitted by each asset beacon **150** of a plurality of asset beacons. Tag **110** also listens to short-range signals that may be transmitted by each asset location beacon **160** of a plurality of asset location beacons. Tag **110** sends location reports to one or more recipients having a location data store **170**, and, if tag **110** is of a staff member that may be assigned to approach assets, tag **110** may also communicate with one or more control **174** for receiving asset-related assignments therefrom.

[0057] Tag **110** includes short-range signal receiver **114** that listens for signals sent by beacons and detects, from signals received from a beacon, the beacon identifier, and may also measure the strength of received signals. Optionally, short-range signal receiver **114** also retrieves from a signal received from a beacon other information, such as a message from an asset relayed via the respective asset beacon. One or more of network communication device(s) **118**, is used for establishing communication via a communication network, such as a Wi-Fi, cellular or Bluetooth network, with location data store **170**, and optionally also with control **174**. User interface **122** provides information to the tag's user via visual and/or audio and/or tactile signals. Memory **126** stores data, while processor **130** includes processing hardware and software for the operation of tag **110**, including the methods taught by the present disclosure. Battery **134** energizes all the units of tag **110**. Sensors **138**, such as an accelerometer, compass, microphone or camera, may be used to detect whether tag **110** is in use or is in motion, and also optionally participate in determining the location of tag **110**. Optional other functions **146** are hardware and software components that serve for the tag offering useful functionalities that are unrelated to the present invention, such as music playing, telephony or outdoors navigation. Optional attachment **142**, such as a lanyard, a belt or a clip, may be used to conveniently attach tag **110**A the tag bearer's body or clothing. Tag **110**A may also be carried in the bearer's handbag or pocket, for example in the case that the tag is actually implemented as a personal smartphone programmed according to the teachings of the present disclosure.

[0058] Asset beacon **150** is a transmitter of a short-range signal, such as an ultrasonic, infrared or low-power RF signal, that is assigned and attached to an asset and effectively becomes part of the asset. It is energized from either a battery (not shown) of from power provided by the asset. Asset beacon **150** is devised to recurrently transmit a short-range signal, for allowing receivers, such as short-range signal receiver **114** of tag **110**, to detect the presence and retrieve the identity of the respective asset. Short-range

signal transmitter **152** transmits the above short-range signal carrying asset beacon identifier **154** and/or asset identifier **156** and optionally messages received from the respective asset via asset interface **158**. Asset beacon identifier **154** is recorded within asset beacon **150** to uniquely identify asset beacon **150** within the site. Asset identifier **156**, such as an inventory number and/or an asset description, is optionally recorded within asset beacon **150**, or it can be retrieved from a lookup table (not shown) includes in the tag's memory **126** or in location data store **170**, against asset beacon identifier **154**. Asset interface **158** is optionally included, typically for more sophisticated and expensive assets, for relaying, via short-range signal transmitter **152**, asset-related status messages such as usage, need for maintenance etc., and can also be used for supplying power from the asset for the operation of asset beacon **150**.

[0059] Location beacon **160** is fixed at a known, selected spot, such as on a wall or a ceiling within the site, for identifying the current zone of a tag **110** that currently communicates with location beacon **160** via short-range communication. Location beacon **160** uses short-range signal transmitter **162** to transmit its location beacon identifier **164**, which, when received by short-range signal receiver **114** of a tag **110**, identifies the current zone in which tag **110** is currently located. The transformation from location beacon identifier **164** to the current zone is made by either processor **130** of tag **110** or at the location data store **170**, using a site map that correlates each location beacon identifier **164** with its actual location within the site. Location beacon **160** can be classified into zone-border beacon or zone-center beacon, as will be elaborated later below.

[0060] Location data store **170** receives location data reports, also called herein greetings, from tags **110**, and stores the received data for being used by control **174**. The location data is preferably organized as a database or another data structure, and correlates asset beacon identifiers and/or asset identifiers with the current known location of each asset. Location data store **170** may be stored on a site server or internet server, on a desktop, laptop or tablet computer or a smartphone, or within memory **126** of tag **110** assigned to a staff member who is in charge of asset management or operates control **174**. Several units of location data store **170** may operate concurrently, for example to serve different types of assets controlled by different controls **174**, or just carry redundant copies of the same asset location data.

[0061] Control **174** is a computerized command post, that includes a processor, and is in a form such as a computer, a tablet, a smartphone or a staff tag, allowing a supervisory staff member, such as an asset manager, shift supervisor or chief nurse, to assign asset-related assignments to other staff members via their tag **110**. When an asset-related assignment, such as maintaining or moving the asset, or authorization to move an asset, is assigned to a staff member bearing a tag **110**, the tag will direct the staff member toward the asset, as will be described later below.

[0062] FIG. **1**B describes system **100**B, that is an alternative embodiment that does not use the location beacons **160** of FIG. **1**A. Instead, one or more of location sensor **138**L serve to identify the current zone where tag **110**A is. Examples of location sensor **138**L will be described in the section LOCATING TAGS WITHOUT USING LOCATION BEACONS below. It will be appreciated that hybrid configurations, that mix both location beacons **160** of FIG. **1**A and one or more methods that do not use location beacons are also feasible, and may be the preferred choice for some sites.

Zoning

[0063] Zoning a site into relatively large zones serves for roughly defining a location of an object. Such division is site-specific, and may be made manually by an administrator under the following considerations: (a) easy recognition of the zone by staff members, for example: "the West Zone on the 3rd floor" or "the imaging division"; (b) efficient and convenient deployment of location beacons or visual features used for identifying the zones (FIGS. **2**B and **2**C below), if such elements are applied; (c) the zone size and layout are easy to manually screen by a moving staff member for finding an asset within the zone; and (d) preferably, effective separation among zones, for example by walls that are impermeable to beacon signals, so that leaks of asset beacon signals between zones are eliminated or reduced.

[0064] FIG. **2**A schematically describes an exemplary division of a floor layout in a healthcare facility into four zones: Elevator Zone near the elevator; West Zone that includes six 3-bed rooms; East Zone that includes three single-bed rooms, and South Zone that is a corridor connecting the east and West Zones. It will be noted that zone names may be arbitrarily chosen by an administrator to be uniquely and easily recognized by the staff, and can be names of divisions, functional names such as the dining area, or legacy names such as "Roberta's hall".

Locating an Asset

[0065] Locating an asset is at least determining the zone in which the asset is currently located. In some cases, when additional information is available, as is the case of detecting an escorting event by a designated mover, such additional information may provide more specific location information; for example, instead of just locating a respiratory machine at the West Zone, it may be located next to bed C in room 305, according to the particulars of the moving assignment sent to the designated mover.

[0066] Locating an asset is usually a two-stage process: (i) locating a tag; and (ii) detecting the asset's beacon by the tag via a short-range signal. This locating process works best when the maximum range of the short-range signal is small relatively to the zone's size, and/or when zones are physically separated by walls that are impermeable to or highly attenuate the short-range signals. As noted above, the locating process may be supplemented by additional location information, as in the case of an escorting event by a designated mover.

[0067] It will be noted that locating the tag and detecting the asset's beacon may be separate events. For example, a staff member's tag detects its entry into the West Zone at 10:00 am, while the tag detects an asset beacon at 10:03 am. Such events are usually combined and interpreted as the respective asset being located at the West Zone at 10:03, especially when the tag is expected to reliably detect its exit from the West Zone.

Using Zone Border Beacons for Locating Tags

[0068] A "zone border beacon" is herein a location beacon positioned on or next to a border between zones, for allow-

ing tags to detect their entering and/or exiting the respective zones. In some of the following exemplary embodiments such location beacons will be described as fixed to the ceiling; it will be appreciated, however, that location beacons may alternatively be fixed to walls or to any stationary objects.

[0069] FIG. **2**B schematically describes deployment of five zone border beacons **220**A-**220**E, devised for allowing tags to detect entry into and exit from the four zones of FIG. **2**A. The zone border beacon is preferably fixed to the ceiling or to a lintel, or possibly to a wall, on or next to the border between the zones. Thus, zone border beacon **220**E is positioned for allowing tags to detect entry to and exit from the elevator into and from Elevator Zone; zone border beacon **220**A and zone border beacon **220**B are positioned for tags detecting moving between the Elevator Zone and the West Zone/East Zone, respectively; while zone border beacon **220**C and zone border beacon **220**D are positioned for tags detecting moving between the South Zone and the West Zone/East Zone, respectively.

[0070] Detection by a tag of crossing the border between zones benefits from the short distance and clear line-of-sight between the tag and the zone border beacon, and by recognizing a peak in the strength or the signal received by the tag from the beacon.

[0071] Deciding whether a border-crossing tag is entering or exiting a zone can be made by counting the number of crossings of the border by the tag. However, to avoid confusion, such as when a tag bearer turns around at the border between zones, asymmetry in the zone border beacon design or in its installation is preferably introduced. FIG. **3** schematically describes a simplified asymmetric design, where zone border beacon **220**A is fixed to ceiling **322**, and shield **324**, such as a small piece of material that is impermeable to the short-range signal emitted from zone border beacon **220**A, is also fixed to ceiling **322** to partially block the short-range signals emitted from zone border beacon **220**A in the direction of the West Zone. The beacon signal strength detected by the tag is schematically depicted by curves **330**A+**330**B as a function of distance from zone border **326** (straight curves are arbitrarily used for simplicity). Assuming that the tag moves with its bearer at a fairly constant speed, the signal vs. time curve looks similar to the signal vs. distance curve of FIG. **3**. Thus, when the tag first detects moderate inclining slope signal strength curve **330**A followed by sharp declining slope signal strength curve **330**B, entry into the West Zone is detected, while when the tag first detects inclining sharp slope signal strength curve **330**B followed by declining moderate slope signal strength curve **330**A, entry into the Elevator Zone is detected. It will be noted that other designs that indicate the direction of motion between zones may be applied, for example placing a pair of beacons at the border between zones, and detecting which of the two respective peaks shows first.

Exemplary Floor Layout

[0072] FIG. **2**B depicts an exemplary floor layout **200**B in a healthcare facility, divided into the four zones of FIG. **2**A. Elevator **204** is used to enter and exit the floor. The West Zone includes six rooms **210-1** to **210-6**, each room hosting three beds A-C. The East Zone includes tree single-bed rooms **210-7** to **210-9**. Zone border beacons **220**A-**220**E serve tags visiting the floor (not shown) for locating their current zones by detecting border crosses, as discussed above. Assets **230**A-**230**D are examples of assets scattered throughout the floor, to be located according to the teachings of the present disclosure. Access points **206**A-**206**C, such as Wi-Fi access points, demonstrate partial network coverage of the floor, which allows a tag **110** to use its network communication device **118** (see FIGS. **1**A-**1**B) to report asset locating events only passing by an access point.

Locating Tags without Using Location Beacons

[0073] FIG. **2**C describes floor layout **200**C that is similar to floor layout **200**B of FIG. **2**B, with the omission of zone border beacons **220**A-**220**E and with the addition of visual features **244**A-**244**D. Retaining the method of locating an asset via combining locating a tag and detecting the asset's beacon by the tag, FIG. **2**C focuses on using one or more of location sensor **138**L (FIG. **1**B) as alternatives to detecting the zone border beacons of FIG. **2**B. Turning opportunities **240**A-**240**L are virtual spots where tags may make sharp turns into or from corridors and rooms. Such turns are detectable by an accelerometer included in sensors **138**, and may sometimes be distinguishable from one another with the assistance of a compass included in sensors **138**.

[0074] With reference also to the zones defined in FIG. **1**A, a tag detecting a sharp right turn at the elevator exit (apparently at turning opportunity **240**A) followed by detecting a sharp left turn (apparently at turning opportunity **240**B) may realize that the tag has entered the West Zone. However, when a further sharp right turn event is detected, it may be hard to determine whether such event occurred in any of turning opportunities **240**D-**240**F—which implies that the tag is located in one of the rooms of the West Zone, or at turning opportunity **240**G—implying that the tag has crossed the border to the South Zone. To resolve such ambiguities, visual features **244**A-**244**D are added, to be detected and recognized by a camera that is included in sensors **138** and is positioned, along with the tag, to look at the same direction as the user bearing the tag. Thus, following the detection of the sharp right turn described above, seeing or missing visual feature **244**C by the camera may indicate being at the South or West Zone, respectively. Visual features **244**A-**244**D are distinctive marks, symbols, patterns, images or colors that are recognized by image processing of the image viewed by the camera, and can be, for example, either arbitrary existing elements, such as a painting hung on the wall, or a sticker or sign showing conventional text of coded with a bar code or QR code. A combination of analyzing all turning opportunities within a floor supplemented by unique visual features positioned at key points may provide reliable locating for tags within the floor area, as an alternative to location beacons.

[0075] Additionally or alternatively, other indoors positioning technologies may also be used for locating a tag. For example, U.S. Pat. No. 8,798,924 teaches a method of using an electronic compass sensor to detect consistent irregularities in the earth's magnetic field caused by steel structures embedded within buildings. The method has been implemented and marketed by IndoorAtlas Inc. of Palo Alto, Calif. Thus, including an electronic compass in sensors **138** of tag **110** and programming the method of the '924 patent above into processor **130** provides another way for locating the current zone of tag **110** without deploying location beacons.

Locating Tags Using Zone Center Beacons

[0076] A "zone center beacon" is a location beacon positioned within a zone, with the purpose of tags locating themselves within the zone upon detecting a short-range signal received from the zone center beacon, or upon detecting that the strength of the signal exceeds a predetermined threshold. It will be appreciated that the term "center" is merely illustrative, and a zone center beacon may be located anywhere within a zone, as long as detecting the beacon indicates being located within the respective zone. Also, a zone may have multiple zone center beacons (not shown in the following figures) that serve to identify the zone. In some of the following exemplary embodiments such location beacons will be described as fixed to the ceiling; it will be appreciated, however, that location beacons may alternatively be fixed to walls or to any stationary objects.

[0077] FIG. **2**D schematically describes floor layout **200**D, wherein fourteen zone center beacons **220-1** to **220-14** are fixed to the ceiling to define fourteen room-size zones. For example, when a tag detects zone center beacon **220-3** (or that the strength of the short-range signal received from zone center beacon **220-3** exceeds a predefined threshold), the tag is considered located within the respective room **210-1**.

[0078] When comparing the exemplary layouts of FIGS. **2**B and **2**C, floor layout **200**D appear to offer an advantage of finer, room-level locating resolution against the disadvantage of higher cost of deploying and maintaining more location beacons. However, smaller zones imply also other disadvantages of false locating and reduced frequency of greetings, as will be elaborated in the section CORRELATION BETWEEN ZONE SIZES AND ASSET BEACON SIGNAL RANGES below.

Dividing a Large Hall into Overlapping Zones

[0079] A specific case where using zone center beacons may be advantageous, is where zones are selected arbitrarily, and the borders among the zones are blurred, as will be clarified with reference to the exemplary floor layout **200**E of FIG. **2**E.

[0080] A large hall **270** is arbitrarily divided into three partly overlapping zones: West Area **260**Z, Central Area **264**Z and East Area **268**Z. Three zone center beacons **260**, **264** and **268** are fixed to the ceiling at the centers of the respective zones. A staff member bearing a tag, such as tag **250**A, happens to currently visit large hall **270**. Upon tag **250**A detecting zone center beacon **260** (or that the strength of the signal received from zone center beacon **260** exceeds a predetermined threshold), tag **250**A locates itself as being currently located within West Area **260**Z, and upon detecting asset **230**A (actually the beacon of asset **230**A) is will author a greeting that locates asset **230**A within West Area **260**Z. It will be noted that tag **250**C will locate itself at both West Area **260**Z and Central Area **264**Z, and accordingly may author a greeting locating asset **230**C at both West Area **260**Z and West Area **264**Z. It will be also noted that asset **230**C will be located at West Area **260**Z by tag **250**A. A recipient of greetings from both tag **250**C (locating asset **230**C at both West Area **260**Z and Central Area **264**Z) and tag **250**A (locating asset **230**C at West Area **260**Z only) may apparently locate asset **230**C at West Area **260**Z. Asset **230**D will be detected by tag **250**D as located at Central Area **264**Z and asset **230**B will be detected by tag **250**B as located at East Area **268**Z. It will be noted that tags **250**A-**250**D may be separate tags borne by separate staff members, or be a single tag moved within large hall **270** by a staff member during routine work, being unaware of the asset locating activities and corresponding greetings sent by his or her tag.

[0081] It will be noted that location ambiguities may be tolerated, or even remain unnoticed by staff members who are directed to approach a located asset. For example, if a staff member is requested to approach asset **230**C, directing her to either West Area **260**Z or Central Area **264**Z may prove very helpful, as long as she does not waste time in looking for the asset in East Area **268**Z. Using homing for finding assets may further alleviate location ambiguities, as will be elaborated later below. The example of FIG. **2**E highlights the fact that zones and borders may partly overlap and afford a certain level of ambiguity.

[0082] FIG. **2**F schematically depicts another exemplary floor layout **200**F, that include sixteen room **1**N-**8**N and **1**S-**8**S, a corridor **280**, and eight location beacons **1-8**, that can zone center beacons and/or zone border beacons, fixed to the ceiling and/or walls of corridor **280**. Tag **9** identifies strong signals received from location beacon **2** and location beacon **3** and accordingly be located in "zone **2-3**", while tag **10** receiving signals from location beacon **3**, location beacon **4** and location beacon **5** may be located in "zone **3-5**". Assets whose asset beacons are sensed by tag **9** or tag **10** (not shown in FIG. **2**F) are reported as located in "zone **2-3**" or "zone **3-5**", respectively, which may be very helpful for a staff member sent to approach such assets. Thus, overlapping zones may still be very useful in practical applications, and such zones may be defined and named in advance, or ad-hoc according to the actual beacons detected by the tags. It will be noted, however, that signal strength analysis and self-learning may substantially narrow asset locating, for example locating tag **10** in "zone **4**" instead of "zone **3-5**".

Correlation Between Zone Sizes and Asset Beacon Signal Ranges

[0083] Locating an asset by a tag involves two primary stages: (i) identifying the tag's current zone, and (ii) detecting the asset via a short-range signal received by the tag from the asset's beacon. The conclusion of the two stages is that the asset is currently located at the tag's current zone.

[0084] Two parameters of interest to the present discussion that affect the effectiveness and dependability of the above locating process are the size of zones and the range of the short-range signal received by tags from asset beacons. Within the current section, the two parameters will be abbreviated "zone size" and "asset signal range", respectively.

[0085] The zone size can be arbitrarily determined by operational and cost considerations when implementing a system according to the present disclosure in a given site. The asset signal range is determined by factors such as: (i) the signal carrier, such as ultrasound, infrared or low-power RF; (ii) the strength of the signal transmitted by the beacon; (iii) the sensitivity of the tag's signal receiver; (iv) a threshold selected for ignoring weak signals received by the tag's signal receiver; and (v) the permeability of physical partitions that form part of the site, such as walls, to the signal transmitted by the asset beacon. Generally speaking, factors (i)-(iii) are a matter of design; factor (iv) allows dynamic range adaptation per site or even per zone, as well as calibration according to learning over time; while factor (v) is usually a given design constraint per site, unless extra partitions are purposely added for separating zones.

[0086] The following considerations may affect the design of specific embodiments of the present disclosure, as well as the settings of the signal threshold (iv) of the previous paragraph:

[0087] The asset signal range should be substantially smaller than the zone size, otherwise identifying the current location of a detected asset with the current location of the detecting tag may often be erroneous. An exception is when the zones are separated from each other by partitions (such as walls) that are impermeable to beacon short-range signals, which is better achieved with ultrasonic or infrared signals, or by shielding RF-permeable inter-zone partitions if RF signals are used. However, it should be noted that signals that are effectively blocked by partitions between zones, may also be blocked by partitions between rooms within a zone, or other random partitions, thereby highly reducing the number and frequency of useful locating reports, which may render the system less effective.

[0088] Operationally, larger zones imply reduced specificity when directing a staff member to an asset: "a respiratory machine at the West Zone on the 3rd floor" is less specific than "a respiratory machine next to bed C in room 305". It is assumed, however, that such reduced specificity is still good enough for directing staff members toward assets in many sites, which makes larger zones acceptable for such sites.

[0089] Smaller asset signal range reduces the number and frequency of useful greetings: A greeting is often authored and reported by a random passing-by tag who happens to detect an asset when moving in its proximity. A small asset signal range implies that some assets that are currently positioned in an area that is seldom visited, may not be detected by tags that pass-by.

[0090] Larger asset signal range introduces locating errors: signals transmitted by an asset positioned at a certain zone and received and reported by a tag at another zone (such signals will be called herein "leaks"), may introduce errors when directing a staff member to the asset, such as when directing the staff member to the West Zone instead of the South Zone because of an asset signal that penetrated a wall between the zones during the locating phase. Such error events may be remedies by using homing as part of the directing process, which will exploit the very leak that created the error for correctly directing the staff member toward the asset, or toward a wall behind which the asset is hiding; also, the staff may get used to a certain low percentage of direction errors and learn to overcome such errors by searching an unfound asset at a neighboring zone.

[0091] Resolving conflicting greetings by the recipient: in a busy site, the recipient of the greetings, such as a site database or an asset manager's portable terminal (see FIG. **4**E below) may receive a plurality of greetings pertaining to the same asset from different tags within a short period of time. Preferably, the strength of the beacon signal received by the tag is included in the greeting (see item (**4**) in FIG. **4**D below), and then greetings associated with stronger signals are considered more significant. Also, in case that there is only a single greeting and it is associated with a weak signal, the tag zone may be then presented as approximate location when directing a staff member to the respective asset.

[0092] It will be appreciated that experience and self-learning may assist in: (i) fine-tuning the zone allocations (and possibly lead to repositioning some respective zone border or zone center beacons, if used); (ii) calibrating the relative weights of location signal strengths received by the greetings recipient; and (iii) the staff members learning to tolerate sporadic direction errors.

Locating People

[0093] The system described above uses tags borne by and moving with people to locate assets via their attached beacons. Tags are typically borne by staff members, but can be also be borne by residents, customers and/or visitors.

[0094] Locating a person as being in a certain zone via locating his or her tag is often useful by itself. Such tag location is reported by default as part of a greeting (see FIG. **4**D), and can also be reported independently of a greeting, for example whenever crossing the border between zones.

[0095] Since people may move a lot, real-time reporting is important, which requires continuous network communication availability, at least next to the passages between zones.

Frequency and Validity of Greetings

[0096] A greeting is preferably time stamped and authored upon a tag detecting an asset. However, the greeting can be forwarded by the tag only when network communication is available. In addition to availability, communication cost and bandwidth may push toward batching several greetings to be sent as a single message.

[0097] Assets are usually stationary during service or storage, and therefore a greeting may be considered valid for minutes or even hours from its time stamp. A greeting expiration time may be set according to an asset type and calibrated by experience; however, in the absence of a fresher greeting, the last greeting received from an asset may be used even past its expiration time.

[0098] A tag that remains in proximity to an asset may detect numerous signals transmitted by the asset. Following authoring a greeting, subsequent signals from the same asset may be ignored for a predetermined period of time, say two minutes, or until a zone change is detected, for example when the asset is moved from one zone to another by the tag bearer.

[0099] The more timely a greeting is, the more dependable is the respective asset locating data. Accordingly, if available and affordable, continuous network coverage throughout the site is highly preferred.

The Locating Process

[0100] FIG. **4**A describes an asset locating process by a tag, in a site that includes location beacons for locating the tag within a zone (for example, as described in FIG. **2**B, **2**D or **2**E). In step **401** the tag listens to beacon signals that may arrive from location beacons (zone border beacons or zone center beacons) or from asset beacons. If in step **405** a beacon signal is detected, then step **409** checks whether the detected signal is from a location beacon or and asset beacon. In case of a location beacon, the current tag zone as determined from the location beacon is recorded in step **413** in the tag's memory, and, if locating persons is implemented and communication is available, then in optional step **413**R the current tag zone is reported to the designated recipient (FIG. **4**E).

[0101] If step **409** determined that the beacon signal is from an asset beacon, then step **417** checks whether that tag zone is recorded in the tag memory as a result of a previous

loop via step **413**, and if so, a greeting is authored by the tag in step **421**, followed by step **425** checking whether communication is available. If communication is available, then in step **429** the greeting authored in step **421** is sent to the designated recipient, possibly along with previous unsent greetings; otherwise the greeting is batched in step **433**, for being sent when communication is available.

[0102] FIG. **4**B describes an asset locating process by a tag using any tag's zone locating method. Thus, in step **401**B the tag's current zone is located using any tag locating method, such as the beacons in FIG. **2**B, **2**D or **2**E; or the turn analysis and/or visual features of FIG. **2**C; or by detection and analysis of irregularities in the earth's magnetic field of U.S. Pat. No. 8,798,924 depicted above; or any other applicable indoor positioning method. In optional step **413**B, the tag's current zone is reported if locating persons is implemented and communication is available. In step **401**B the tag listens to asset beacon signals. If in step **405**B an asset beacon signal is detected, then a greeting is authored in step **421**. If step **425** finds out that communication is available, then in step **429** the greeting authored in step **421** is sent to the designated recipient, possibly along with previous unsent greetings; otherwise the greeting is batched in step **433**, for being sent when communication is available.

[0103] FIG. **4**C describes an asset locating process similar to the process of FIG. **4**B, while also checking and reporting escorting events. Thus, in step **401**B the tag's current zone is located using any tag locating method. In optional step **413**B, the tag's current zone is reported if locating persons is implemented and communication is available. In step **401**B the tag listens to asset beacon signals. If in step **405**B an asset beacon signal is detected, then in step **419** the tag checks whether the tag and the detected asset are in escorting mode, which is when the tag and the asset maintain a closed proximity for a duration of at least a predetermined period of time, such as thirty seconds, and the tag detects that it has moved during that period, such by detecting change of zone or according to motion detection by an accelerometer included in the tag's sensors **138** (FIG. **1**). If escorting is not detected, then a greeting is authored in step **421**; otherwise is step **421**E, a greeting message that include escorting information (FIG. **4**D) is authored. If step **425** finds that communication is available, then in step **429** the greeting authored in step **421**/**421**E is sent to the designated recipient, possibly along with previous unsent greetings; otherwise the greeting is batched in step **433**, for being sent when communication is available.

Greeting Contents

[0104] FIG. **4**D schematically describes the contents of a greeting **440** sent by a tag to a recipient, to report that the tag has detected asset X in zone Y. Out of fields (**1**)-(**8**) of the greeting, only field (**6**)—the identity of the detected asset—is mandatory, while the other seven fields may be optional, implicit, or otherwise available to the recipient.

[0105] Field (**1**) identifies the greeting recipient or recipients (see FIG. **4**E) which may be the same for all greetings in the site (e.g. a site server) hence redundant. Field (**2**) identifies the sending tag, which may be also derived from the network communication protocol hence redundant. Field (**3**) indicates the time when the tag detected the presence of the asset, which may be essentially identical to the time of receiving the message by the recipient, if real-time communication is implemented. Field (**4**) reports the strength of the beacon's signal detected and measured by the tag, if this feature is implemented; weaker signals may indicate larger distance and/or obstructions between the tag and the beacon, which may assist the recipient in deciding between conflicting greetings received at a similar time from different tags and locating the same asset at different zones.

[0106] Field (**5**) reports the zone where the asset is located, which is the zone where the tag is or has been located at the moment of detecting the tag's location. In implementations of the present disclosure where persons are continually located by their tags and where greetings are sent in real-time, the current zone of the tag may already be known to the greeting recipient, which may make field (**5**) redundant.

[0107] Mandatory field (**6**) identifies the detected asset, directly or via identifying the respective beacon attached to the asset, such as by inventory number and/or detailed description.

[0108] Field (**7**) indicates whether the greeting is produced in connection with an escorting event (FIG. **4**C) which usually suggests that the detected asset has been moved by the tag bearer. Such information can be useful in various ways: (a) identifying unauthorized moving of assets; (b) referring questions regarding the current location of the asset to the respective tag bearer; (c) identifying the current mover as the preferred mover for the next moving of the same asset, since the current mover is already familiar with the current location of the asset within the zone; or (d) if the reporting tag is borne by a designated mover of the asset, the asset may be presumed to have been relocated to the designated moving target location, such as "next to bed C in room 305".

[0109] Field (**8**) is for implementations where the asset beacon **150** includes and employs an asset interface **158** for receiving status messages from the asset, such as usage, material inventory or need for maintenance. Such messages are included in field (**8**) to be handled by the message recipient.

Recipients of Greetings

[0110] A greeting is intended to update a location data store **170** of a recipient, as to where the respective asset is located. FIG. **4**E schematically introduces three typical recipients that may benefit from receiving greetings.

[0111] In a common scenario, greeting-sending tag **450** addresses its greetings to site server **458** such as a central hub of administrative information in the site. Any would-be user of asset location information may then connect with site server **458** for retrieving the requested information.

[0112] Alternatively or additionally, in sites that employ an asset manager who is in charge of assets, greetings may be sent to asset manager's portable terminal **454**, such as a tablet, mobile phone, or an enhanced staff tag, to allow the asset manager to conveniently and continuously monitor all assets.

[0113] Alternatively or additionally, in sites that employ staff members who are often assigned moving tasks, an extended asset mover's tag **462** may receive greetings from greeting-sending tags **450**, so that when the mover is sent to urgently fetch "the yellow respiratory machine" he'll have the respective location information readily-available at hand in his staff tag. Optionally, such location data may be retrieved on-demand, by asset mover's tag **462** sending a query to all tags, which can be informally described as asking all tags "who has seen the yellow respiratory machine

during the last hour?", which is then responded by greetings sent from only the tags which have recently detected the sought asset.

Escorting

[0114] FIG. **5** further elaborates on escorting events depicted above with reference to steps **419** and **421**E of FIG. **4**C.

[0115] Detection of escorting events comes to identify that an asset is moved by a tag bearer, usually a staff member. A first condition for escorting is learning, from the asset beacon signal received by the tag, that the asset and the tag are in close proximity. To avoid false detection of an escorting event when the tag just passes by the asset, a second condition for escorting is ensuring that the close proximity is maintained for a prolonged duration, such as 30 seconds or more. To further avoid false detection in case that a staff member happens to stand in close proximity to an asset for a prolonged time, such as a nurse standing next to an asset while taking care of a resident, a third condition is detecting that the tag, apparently together with the asset, have moved while maintaining the close proximity.

[0116] In step **501** a tag seeks signals from asset beacons and in step **505** an asset beacon is detected. Step **509** learns from the strength of the signal received from the asset beacon whether the asset and the tag are in close proximity, such as a meter or less. If yes, then step **513** checks whether the close proximity is maintained for a prolonged duration, such as thirty seconds or more. If so, then step **515** checks whether the tag has moved while the closed proximity has been maintained, for example by detecting that the tag has crossed a border between zones and/or by consulting an accelerometer or camera included in sensors **138** of the tag. Positive outcomes in all three steps **509-515** identifies an escorting event, which implies that the asset has been moved by the tag bearer, which conclusion is identified and/or reported in step **519**. Step **525** checks whether the staff member bearing the tag had a moving assignment for the detected asset, and if yes, then step **529** sets the current location of the asset according to the target of the moving assignment, such as next to bed C in room 305, which is more specific than locating the same asset at the West Zone as in the general locating case.

[0117] It will be appreciated that while steps **501-515** are performed by the tag, steps **519-529** may be performed by the tag, or, additionally or alternatively, by recipients to which the tag reports, such as site server **458**, asset manager's portable terminal **454**, or asset mover's tag **462** of other movers (see FIG. **4**E). In any case, the end result of the process is that the current location of the moved asset is updated to be the target location specified in the moving assignment.

Directing a Staff Member Toward a Tag

[0118] FIG. **6** describes a process of directing a staff member toward an asset for performing an asset-related task, such as repairing, replenishing supplies, moving the asset to a new location, or just visiting the asset by a security attendant. The steps on the left hand side of the chart are performed by a control computing device (see control **174** in FIG. **1**A), while the steps on the right hand side are performed by the tag of a staff member designated to approach the asset.

[0119] In step **601** control generates or receives a task that requires visiting a specific asset, herein called asset X. Generation of a task by control can be made automatically for repair, replenishment or security tasks, or entered manually into the control by a supervisor, for example when the asset is needed in a certain place, in which case the task is an asset relocation task. In step **605** control retrieves the identifier of the beacon attached to asset X, for example from location data store **170** of FIG. **1**A, and in step **609** control retrieves, also from location data store **170**, the current zone of asset X most recently reported by a locating process, such as the processes of FIG. **4**A-**4**C or **5** above. In step **613**, a staff member is selected for performing the task, which can be made automatically, for example where there is just a single staff member on duty that is suited for the task, or via a manual input received by control from a supervisor. In step **617**, the description of asset X, the current zone of asset X, the respective beacon identifier and the task description are provided by control to the staff tag of the selected staff member.

[0120] In step **621** the staff tag of the selected staff member receives the data provided by control in step **617**. In step **625** the tag presents the zone to and is moved to the zone by the staff member who bears the tag. Step **629** initiates a homing process, in which the tag seeks signals that carry the beacon identifier, and when such signals are detected, the tag guides the staff member toward the asset by providing homing indicia toward the beacon (FIGS. **7**A-**7**C below). In step **631** the tag reaches asset X, which enables the staff member to perform the task.

[0121] Steps **633-641** pertain to the case where the assigned task is moving the asset to a new target location. In this case, in step **633** the tag detects an escorting event, which implies that the asset is moved by the staff member who bears the tag. In step **637** the tag detects, from the weakening or disappearance of the beacon signal, the departure of the staff member from the asset hence the purported completion of the moving task, which lets control, in step **641**, to record the new location of asset as the target of the moving task.

Homing

[0122] FIGS. **7**A-**7**C summarize and highlight some aspects relating to homing, in addition to aspects pertaining to homing presented in pervious sections. FIG. **7**A presents an asset **700** to which an asset beacon **700**B is attached. Asset beacon **700**B recurrently transmits short-range signal **704**, such as an infrared, ultrasonic or a low-power RF signal, which is received by short-range signal receiver **114** of tag **110**. Tag **110** interprets short-range signal **704** for both identifying asset beacon **700**B and measuring the strength of the received signal, which is generally proportionate to the distance between the tag and the asset. Display **122**D and/or speaker/earphone **122**A serve to provide visual and/or audio indicia of the current measured signal strength, which serve to guide the staff member who carries the tag toward the beacon, hence toward the asset. FIG. **7**B schematically describes indicia displayed on display **122**D of tag **110**. Thus, text **720** displays the signal strength in numeric terms, preferably using distance units for presenting the estimated distance between the tag and the asset derived from the signal strength; signal level bar **710** shows graphically current signal level **710**L; while beacon pointer **714** show the estimated beacon direction, derived from a series of

signal strength readings during the motion of the tag in combination with readings from a compass and/or accelerometer included in sensors **138** (FIG. **1**A).

[0123] FIG. **7**C schematically demonstrates how homing may remedy locating errors, using a scenario based on the southwest corner of the floor layout of FIGS. **1**A-**1**B. An asset **230** is located in a corridor **212** that is very rarely visited by tag-bearing persons. The corridor **212** has been assigned to the South Zone, while a frequently visited neighboring room **210** has been assigned to the West Zone. The wall between room **210** and corridor **212** is sufficiently permeable to RF asset beacon signal **230**S to allow a tag **250** visiting room **210** to detect asset **230**. During the locating phase, several tags visiting room **210** mistakenly report that asset **230**A is located at the West Zone, and its correct location in the South Zone is not reported simply because no tag happens to visit the deserted corridor **212**. However, when a staff member is directed to visit asset **230** in the West Zone, he uses his tag **250** to quickly screen all the rooms of the West Zone, including room **210**. When in room **210**, tag **250** detects asset **230** via RF asset beacon signal **230**S, and the homing process directs the tag bearer toward the wall, which will lead most reasonable staff members to search and find asset **230** behind the wall, in corridor **212** that belongs to the South Zone. Thus, the very leak that causes the locating error during the locating phase helps to recover from this error during the directing phase.

Blind Areas

[0124] A "blind area" is an area that may host assets but is seldom or never accidently visited by passing-by tags. FIG. **8**A schematically describes floor layout **800**A that includes blind area **802**A and blind area **802**B that are positioned at dead ends of a corridor and are visited just once a day by the cleaner, while blind area **802**C is a closet or a storage room that may store assets.

[0125] Blind areas may collectively form a "blind zone" that is systematically screened by staff members when an asset is not found in its last reported location, or security personnel or other staff members may be directed to periodically, say once per hour, pass through all blind areas. Such a security screening may also be initiated when a certain asset is not reported by any greeting during an extended period of time, say three hours. Alternatively, an asset beacon detector **820** may be used to cover a blind area, as described below with reference to FIG. **8**B.

Security and Beacon Detectors

[0126] It is a clear interest of a site to prevent assets from being stolen or misplaced to another floor or section.

[0127] Beacons should preferably include tamper-detection sensors that turn on an audible alarm and/or turn the beacon's short-range signal into an alarm signal. Accordingly, routinely locating an asset within its designated area verifies that the asset has not been misplaced or stolen.

[0128] On the other hand, failure to locate an asset for extended time may imply either that the asset has been misplace or stolen, or that the asset is currently located in a blind area. Both situations can be preempted by deploying beacon detectors in selected areas.

[0129] A "beacon detector" is essentially a tag that is fixed at a selected location, such as a ceiling or a wall, for detecting assets in its proximity. Its design is similar to tag **110** of FIG. **1**A, modified for continuous operation in a fixed location, which implies continuous network connection and preferably drawing energy from the site's electrical network.

[0130] FIG. **8**B describes a floor layout **800**B that employs beacon detectors for timely locating and detecting assets. Floor layout **800**B has two exits: elevator **204** and staircase **806**. Security beacon detectors **820**A-**820**B are preferably fixed next to the exits, and upon detecting an approaching asset and checking that moving the asset has not been authorized, the event is reported, an alarm may be triggered and/or the respective exit may be locked. Beacon detectors **810**A-**810**C are fixed in the blind areas **802**A-**802**C of FIG. **8**A, and periodically report the location of assets that are contained within the blind areas.

Multi-Function Smart Devices

[0131] The active devices discussed so far can be divided into:

[0132] (a) tags borne by persons for detecting beacons,

[0133] (b) location beacons for assisting tags in locating themselves within zones,

[0134] (c) asset beacons for being detected by tags, and

[0135] (d) fixed beacon detectors that are tag-like devices fixed within blind areas or at exits.

[0136] In some embodiments it may be advantageous to combine several tag/beacon functions into a single enhanced smart device as described below.

[0137] Referring to FIG. **9**A, smart device **900** is devised to serve as an enhanced tag or enhanced fixed beacon detector. Short-range signal transceiver **904** may act, in addition to receiving short-range signals as in the case of short-range signal receiver **114** of tag **110** in FIG. **1**A, also as a short-range signal transmitter, allowing smart device **900** to act also as a beacon. Network communication device(s) **908** may be enhanced to not only act as a network connection means that serves tag **110**, but also as an access point that serves other smart devices that lack a continuous network connection of their own and pass by smart device **900**; for example, network communication device(s) **908** may use both a cellular network connection and a local Wi-Fi or Bluetooth link to offer a cellular hotspot to passing-by smart devices. User interface **912** may be reduced or eliminated in comparison to user interface **122** in case that smart device **900** is fixed to a location. Processor **130** is enhanced, compared to processor **130** of tag **110**, to accommodate the added functionalities described herein. In case of a fixed installation, power supply **924** may draw power from the site's electrical network, and sensors **928** may be eliminated or reduced to camera-only, for example. Attachment **932** may be suited for fixed installation, while other functions **936** may be nullified in case that smart device **900** is dedicated solely to location-related functions.

[0138] FIG. **9**B uses a floor layout **940** for demonstrating several exemplary smart device implementations. Smart devices **948** are positioned in blind areas **944** for detecting assets and reporting their location. A smart device **948** is preferably fixed to the wall or ceiling within or next to the respective blind area, and is preferably equipped with continuous network connection and draws power from the site's electrical network. Smart device **954** is positioned next to the elevator door and may serve several functions: (i) a zone border beacon for allowing tags locate their entry into or exit from the Elevator Zone; (ii) a security object detector for detecting objects that are not permitted to leave the zone

without suitable escorting; (iii) a network communication access point allowing passing-by tags establish network connection. Smart device **952** may be similar to smart device **954**, preferably except the beacon functionality. Smart devices **950** in a minimal configuration may operate as both zone border beacons (see **220**A-**220**D of FIG. **2**B) and access points that provide network communication to tags upon crossing borders between zones, which implies continuous zone-level locating of all tag-bearing persons crossing the respective borders. Smart devices **950** may be further enhanced, to act also as beacon detectors, in which case zone-level locating of all assets can depend on smart devices **950+954** alone, thereby obviating that need for locating and greeting activities by moving tags **250**. It will be appreciated, however, that in order to depend solely on smart devices **950** for asset location, continuous electricity and communication supply to smart devices **950** become mandatory, which requires substantially more investment in infrastructure modifications, compared to when using zone border beacons as in floor layout **200**B of FIG. **2**B, since beacons can operate for months and years on battery power and the configuration of FIG. **2**B does not mandate continuous communication at each location beacon. Accordingly, in some cases an installation of a locating system according to the present disclosure can start with zone border beacons **220**A-**220**D of FIG. **2**B, and be later upgraded by supplementing or replacing zone border beacons with smart devices **950** of FIG. **9**B, which may be made gradually or at once. Smart device **958** is essentially identical to tags **250**, with the addition of a mobile access point, such as a mobile Wi-Fi hotspot that connects to the network via cellular communication, for serving simpler passing-by tags that have no cellular communication of their own.

Multi-Level Border Control

[0139] Asset security has been discussed above with reference to FIG. **8**B, where security beacon detectors **820**A+**820**B positioned next to the exits from the floor area detect approaching assets and trigger an audible alarm and/or lock the respective exit upon finding out that moving the asset out of the floor area has not been authorized. It will be appreciated that such alarm or exit lock events may be annoying to uninvolved persons in the area, and the following arrangement comes to reduce the frequency of such annoyance by earlier detection and preemption of such events.

[0140] The forthcoming discussion covers locating and securing both assets and persons, and will therefore relate to locating and securing "restricted objects" that require authorization in order to move or be moved out of a predefined area, called herein a "confined area". Restricted objects can be "restricted assets" that are supposed to stay at a predefined confined area, or persons, such as certain residents ("restricted residents") in a healthcare facility, that require special attention and supervision.

[0141] FIG. **10**A depicts a of a confined area **960** that accommodates restricted object **964**A and restricted object **964**B, each can be an asset or a person that is designated to normally stay only within the safe area. The term "area" is used herein to avoid confusion with the term "zone" used above, and it will be appreciated that both zones and areas may be used concurrently in sites that implement both general locating as depicted above, and the security feature discussed herein below. A "buffer area" is an area where a restricted object is not supposed to stay without authorization, but is otherwise harmless. Authorization may be in the form of a temporary permit received from a senior staff member, or by recognizing that the object is accompanied by an authorized person, such as a designated staff member or a trusted family member identified by his or her tag or beacon. Such escorting may be recognized by a tag of an authorized person or of a restricted object that detects that close proximity is maintained between the authorized person and the restricted object for an extended period of time, similarly to detecting escorting events according to FIG. **5**, or by detecting simultaneous proximity of both a restricted object and an authorized person to a fixed tag or beacon. The buffer area is preferably used to provide an early warning and early intervention opportunity for staff intervention, in case that a restricted object is detected entering or within the buffer area without authorization. If a restricted object further moves or is moved through the buffer area and is detected to appear without authorization at the "lock area", some or all exits from the lock area, such as elevator **204** and/or the door of staircase **906**, automatically lock, possibly selectively according to that detected location of the restricted object, to minimize annoyance to uninvolved persons. If, for one reason or another an exit fails to lock, as may occur in the case of "tailgating", i.e. a restricted person following an unrestricted person while keeping the exit open, the restricted object enters without appropriate escorting the "alarm area", which is not explicitly marked in FIG. **10**A, and consists of the elevator **204** and the staircase **906**, which triggers an alarm. It will be appreciated that a generous buffer area will effectively eliminate the great majority of exit locking events, while a sufficient lock area may turn alarms into extremely rare occasions. It will be noted that in a certain embodiments, different restricted objects or groups of restricted objects within the same floor may be allocated separate safe areas, in which case safe areas and buffer areas may be individually allocated for such objects or groups of objects.

[0142] It will be appreciated that the terms safe area, buffer area, lock area and alarm area defined above are used for brevity and clarity, and represent concepts that may be described and elaborated using alternative terms without deviating from the underlying structural, logical and operational concepts.

[0143] In the embodiment of FIG. **10**A, object beacon **966**A is attached to restricted object **964**A while object beacon **966**B is attached to restricted object **964**B, where the term attached preferably means physical attachment in case of an asset, or a convenient wearing or carrying arrangement in case of a person, with tamper-detection means possibly implemented in both cases. Fixed tag **968**B and fixed tag **968**C are positioned at the passages between the safe area and the buffer area for detecting entry of a restricted object into the buffer area. Optionally, additional fixed tags **962**B may be scattered within the buffer area to detected restricted objects with the buffer area. Possibly, in some implementations, fixed tag **968**B and fixed tag **968**C, as well as fixed tags **962**B, may also be configured to autonomously detect and select nearby staff members and alert them, via their tags, to handle the event and move or accompany the respective restricted object back to the safe area. Fixed tag **968**D and fixed tag **968**E are positioned at the passages between the buffer area and the lock area for detecting entry of a restricted object into the lock area. Optionally, additional fixed tags **962**L may be scattered within the lock area

to detected restricted objects with the lock area. Possibly, in some embodiments, fixed tag **968**D and fixed tag **968**E, as well as fixed tags **962**L, are preferably also configured to autonomously send a locking signal to the elevator **204** and door of staircase **906**. It will be appreciated that the concept of locking an elevator may be actually implemented by preventing the elevator door from closing, or by disabling the elevator altogether trough the elevator's controller (not shown). Fixed tag **968**F and fixed tag **968**G are positioned at the exits, i.e. the passages between the lock area and the alarm area, for detecting entry of a restricted object into the alarm area, i.e. within the elevator or staircase. Possibly, in some implementations, fixed tag **968**F and fixed tag **968**G are also configured to autonomously trigger an audible alarm and initiate an alarm event procedure such as calling for intervention by security personnel. It will be appreciated that fixed tags **968**B-**968**G, **962**B and **962**L in the exemplary embodiment of FIG. **10**A, are beacon detectors fixed at a selected points, such as on a ceiling or a wall, for detecting object beacons in their proximity. Their design is similar to tag **110** of FIG. **1**A, modified for continuous operation in a fixed location, which preferably implies continuous network connection and drawing energy from the site's electrical network.

[0144] FIG. **10**B depicts an embodiment of a confined area **970** that is similar to the embodiment of FIG. **10**A, except for swapping the roles of tags and beacons. Thus, in confined area **970**, restricted object **974**A and restricted object **974**B bear smart object tag **976**A and smart object tag **976**B, respectively. Border beacon **978**B and border beacon **978**C cooperate with the smart object tags to detect, by the tags, crossing the border between the safe area and the buffer area; border beacon **978**D and border beacon **978**E cooperate with the smart object tags to detect, by the tags, their crossing the border between the buffer area and the lock area; and border beacon **978**F and border beacon **978**G cooperate with the smart object tags to detect, by the tags, their crossing the border between the lock area and the alarm area. Location beacons **972**B and **972**L are optionally added for the detection of restricted objects, by their tags, within the buffer area and lock area, respectively. It is the smart object tags that either report border crossings or unauthorized location to a control, or are configured to autonomously trigger a staff, lock or alarm action respective to the detected border crossing, as depicted with reference to FIG. **10**A above.

[0145] FIG. **10**C describes a scenario of a confined area **980** that is similar to the scenario of FIG. **10**A, except that fixed tags **968**B-**968**G are replaced by cameras **988**B-**988**G, respectively; while object beacons **966**A-**966**B are replaced by visual features **986**A-**986**B, respectively. Visual features **986**A-**986**B may identify restricted objects either individually, for example by including a machine-readable identifier, such as a machine-recognizable text, QR code or bar code, or identify group of restricted objects, such as restricted residents or restricted assets, for example by a distinctive color of a label or a dress. When any of cameras **988**B-**988**G detects any of visual features **986**A-**986**B crossing a border between zones, a respective processor, such as the processor of a fixed tag that includes the camera or of a control reported by the camera, may actuate an action such as calling for staff intervention, locking exits or triggering an alarm, as depicted above with reference to FIG. **10**A. In some embodiments, for security and/or restricted resident dignity, visual features may be marked in the invisible spectrum, for example in the infrared spectrum, with the cameras using appropriate filters to recognize such visual features. It will be appreciated that additional cameras may be fixed and operate within the buffer area and the lock area similarly to tags **962**B and tags **962**L of FIG. **10**A.

[0146] It will be noted that by using fixed tags that include cameras, the scenarios of confined area **960** and confined area **980** may be combined, so that some restricted objects may be detected and identified by their object beacons, while other restricted objects may be detected and identified by their visual features. It will be also noted that that architectures of FIGS. **10**A-**10**C may be combined and mixed, for example by restricted residents bearing tags while restricted assets having beacons attached to them.

[0147] It will also be noted that in the embodiments of FIG. **10**A-**10**C, a tag or a camera cooperates with a beacon or a visual feature to recognize that an asset is moving from one area to another or is already in the buffer or lock area. There are two further steps that may be performed, according to the system architecture, by either the tag or by a control (such as control **174** of FIGS. **1**A-**1**B) to which the tag or camera is reporting: (a) deciding whether the detected moving of the respective restricted object is authorized or not; and (b) triggering an action, such as: selecting and calling staff members to intervene; locking exists; or actuating an alarm.

[0148] FIG. **11**A depicts the operation of the multi-level border security arrangement described with reference to FIGS. **10**A-**10**C above. In step **1001**, a restricted object, such as a person or an asset, is detected crossing a border between areas. Such detection is made via a tag detecting a beacon under the arrangement of either FIG. **10**A or the arrangement of FIG. **10**B, or by a camera detecting a visual feature under the arrangement of FIG. **10**C. Step **1005** decides whether the border crossing is authorized or not. If the border crossing is authorized, by either a permit received via communication from a supervisor, or by verifying, via a personal tag or beacon of a person that maintains close proximity to the restricted object, that the restricted object is accompanies by a person authorized to move the restricted object, then step **1005** loops back to wait for another border crossing detection. If step **1005** concludes that the border crossing is not authorized, then step **1009** decides, according to the type of border crossed, what action to take. If the detected crossing is from the safe to the buffer area, then step **1013**A triggers a notification to the tag or tags of one or more selected staff members in the vicinity of the crossing point, to rush and accompany the crossing restricted object back to the safe area. In the action is picked and acknowledged in steps **1013**B by one of the notified staff members, then in step **1013**C the incident is reported; if step **1013**B does not receive acknowledgement within a short period, then the process loops back to step **1013**A to call for action of additional staff members. If the crossing is found by step **1009** to be from the buffer to the lock area, then step **1017** triggers locking or disabling the respective exist(s), such as the elevator and the staircase door. If the crossing is found by step **1009** to be from the lock area to the alarm area, then step **1021** triggers an alarm. If the crossing is found by step **1009** to be downstream, i.e. from the alarm to the lock area, from the lock area to the buffer area, or from the buffer area to the safe area, then step **1025** triggers a step-back proce-

dure, such as turning an alarm off or unlocking exits, and an update describing the crossing event is sent to the involved staff members.

[0149] FIG. **11**B is similar to FIG. **11**A, except that a restricted object is first detected in step **1001**A within the buffer area, lock area or alarm area, instead of at the respective border; for example, when the detection is made by fixed tags **962**B or fixed tags **962**L within the respective area (FIG. **10**A), rather than at the respective borders by fixed tags **968**B-**968**E. Step **1005**A compares the current location to the last known location to interpret that current location as a border crossing event, and checks whether the crossing was authorized. If crossing is found not authorized, then step **1009**A diverts to actions according to the nature of the crossed border, as depicted in FIG. **11**A above.

[0150] FIG. **12** is a flowchart that describes an authorized relocation process of a restricted object. In step **1201** a restricted object is moved to a new location according to the process of FIG. **11** or FIG. **11**A. Since all border crossings are authorized, all border crossings are performed without step **1005**/**1005**A triggering any of the actions that follow step **1009**/**1009**A. When reaching the intended location, then step **1205** resets the definitions of the safe area and buffer area of the moved object according to the new current location. For example, in a healthcare facility, a restricted resident is escorted by a staff member to a large dining room for lunch and is left by himself at the dining room, that resident's safe area may be redefined to encompass the dining room, and leaving the dining room without escorting by an authorized person will then trigger step **1013**A of FIG. **11**/**11**A. Such relocation and redefinition of the safe and buffer areas may be recorded centrally, in a system that tracks objects and/or personalizes safe areas per restricted object, or just be established de-facto, by the very presence of a restricted object in a new area that is generally defined as a safe area.

[0151] It will be reemphasized that the steps of FIGS. **11**A, **11**B and **12** may be performed, according to selected system architectures, individually or cooperatively, by processors of a staff tag, a resident tag, an asset tag, a fixed tag or a control. Accordingly, the expression "at least one processor" that perform part or all of the steps of the process of FIG. **11**/**11**A may relate to performing steps by any one or combination of processors included in participating tags, controls and/or servers.

Non-Healthcare Applications

[0152] For clarity and consistency, the exemplary embodiments depicted above related primarily to healthcare facilities. It will be appreciated, however, that the teachings of the present disclosure may selectively pertain a to variety of institutional sites, such as manufacturing plants, educational institutions, government buildings, office building, ships, etc., that can benefit from zone-level locating of objects or multi-level border control.

Self Learning, Calibration and Improvement

[0153] The systems and methods depicted above are expected to produce tangible and measurable results in locating and securing assets, in effectively directing staff members toward selected assets, and in border control within sites. Exceptions are easily noticed: an asset whose location remains unknown for a prolonged duration; misdirecting a staff member toward an asset; or a staff member spending excessive time in screening a zone for finding an asset.

[0154] Exceptions may be automatically detected at location data stores and controls (FIG. **1**B), and/or manually reported by staff members. Such exceptions may motivate and guide redefining zones, better placing location beacons, adding beacon detectors, changing the sensitivity threshold of tag receivers, upgrading the network communication, or revising the criteria for deciding between conflicting locating reports.

[0155] Improvement can be also made by educating and training staff members with regard to where to move assets that completed a task, for example into pre-assigned asset parking areas; how to report the location of an unused asset; or who is authorized to move a certain asset. Visitors may also be educated, via signs and brochures, to request staff assistance for moving an unused asset and never move an asset by themselves.

[0156] The above measures may substantially improve the performance of locating and securing assets with minimal additional investment in hardware and installation.

CONCLUSION

[0157] The systems and methods taught by the present disclosure provide a compact locating and directing system for assets and people, that can be afforded by and adequately serve many sites that cannot or will not afford conventional RTLS, access control or security systems.

[0158] While the invention has been described with respect to a limited number of embodiments, it will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described herein. Rather the scope of the present invention includes both combinations and sub-combinations of the various features described herein, as well as variations and modifications which would occur to persons skilled in the art upon reading the specification and which are not in the prior art.

What is claimed is:

1. A method of operation of a tag of a person for directing the person toward target assets, the method comprising:

receiving a target asset identifier and a zone associated with the target asset;

presenting to the person a description of the target asset;

presenting to the person directions for reaching the zone;

seeking beacon signals that match a beacon identifier of a beacon attached to the target asset; and

upon detecting a beacon signal that matches the beacon identifier: producing a series of human-comprehensible homing directions for approaching the target asset.

2. The method of claim **1**, wherein the directions for reaching the zone include at least one of a name of the zone or instructions for reaching the zone.

3. The method of claim **1**, wherein said presenting directions includes at least one of: displaying text instructions, displaying graphical guidance, or playing audio instructions.

4. The method of claim **1**, wherein said producing a series of homing directions includes at least one of: displaying a textual representation of a current strength of the detected beacon signal, displaying a textual guidance regarding the direction of the beacon, displaying a graphical representation of a current strength of the detected beacon signal, displaying a graphical guidance regarding the direction of

the beacon, playing an audio signal that is indicative of the current strength of the detected beacon signal, or playing an audio guidance regarding the direction of the beacon.

5. The method of claim **1**, wherein the person is a staff member designated to relocate the target asset, the method further comprising:

receiving a relocation assignment identifying a target location for the target asset;

detecting short-range beacon signals transmitted by a beacon of the target asset;

learning from the beacon signals that the staff tag and the beacon have reached close proximity;

measuring the duration of the close proximity;

checking whether the staff tag has moved while the close proximity has been maintained; and

based on the results of the measuring and the checking: locating the target asset at the target location.

6. The method of claim **5**, wherein at least said locating the target asset is performed by a recipient device to which the tag reports.

7. A tag for directing a person toward target assets, the tag comprising:

a short-range signal receiver;

a network communication device;

a user interface; and

a processor controlling the short-range signal receiver, the network communication device and the user interface, the processor is programmed to:

receive via the network communication device a target asset identifier and a zone associated with the target asset,

present to the person via the user interface a description of the target asset,

present to the person via the user interface directions for reaching the zone,

seek via the short-range signal receiver beacon signals that match a beacon identifier of a beacon attached to the target asset, and

upon detecting a beacon signal that matches the beacon identifier: produce via the user interface a series of human-comprehensible homing directions for approaching the target asset.

8. The tag of claim **7**, wherein the directions for reaching the zone include at least one of a name of the zone or instructions for reaching the zone.

9. The tag of claim **7**, wherein said present directions includes at least one of: display text instructions, display graphical guidance, or play audio instructions.

10. The tag of claim **7**, wherein said produce a series of homing directions includes at least one of: display a textual representation of a current strength of the detected beacon signal, display a textual guidance regarding the direction of the beacon, display a graphical representation of a current strength of the detected beacon signal, display a graphical guidance regarding the direction of the beacon, play an audio signal that is indicative of the current strength of the detected beacon signal, or play an audio guidance regarding the direction of the beacon.

11. The tag of claim **7**, wherein the person is a staff member designated to relocate the target asset, the processor is further programmed to:

receive via the network communication device a relocation assignment identifying a target location for the target asset;

detect via the short-range signal receiver short-range beacon signals transmitted by a beacon of the target asset;

learn from the beacon signals that the staff tag and the beacon have reached close proximity;

measure the duration of the close proximity;

check whether the staff tag has moved while the close proximity has been maintained; and

based on the results of the measuring and the checking: locate the target asset at the target location.

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