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(54) **SYSTEM AND METHOD FOR LOCATION TRACKING OF PATIENTS IN A VITAL-SIGNS MONITOR SYSTEM**

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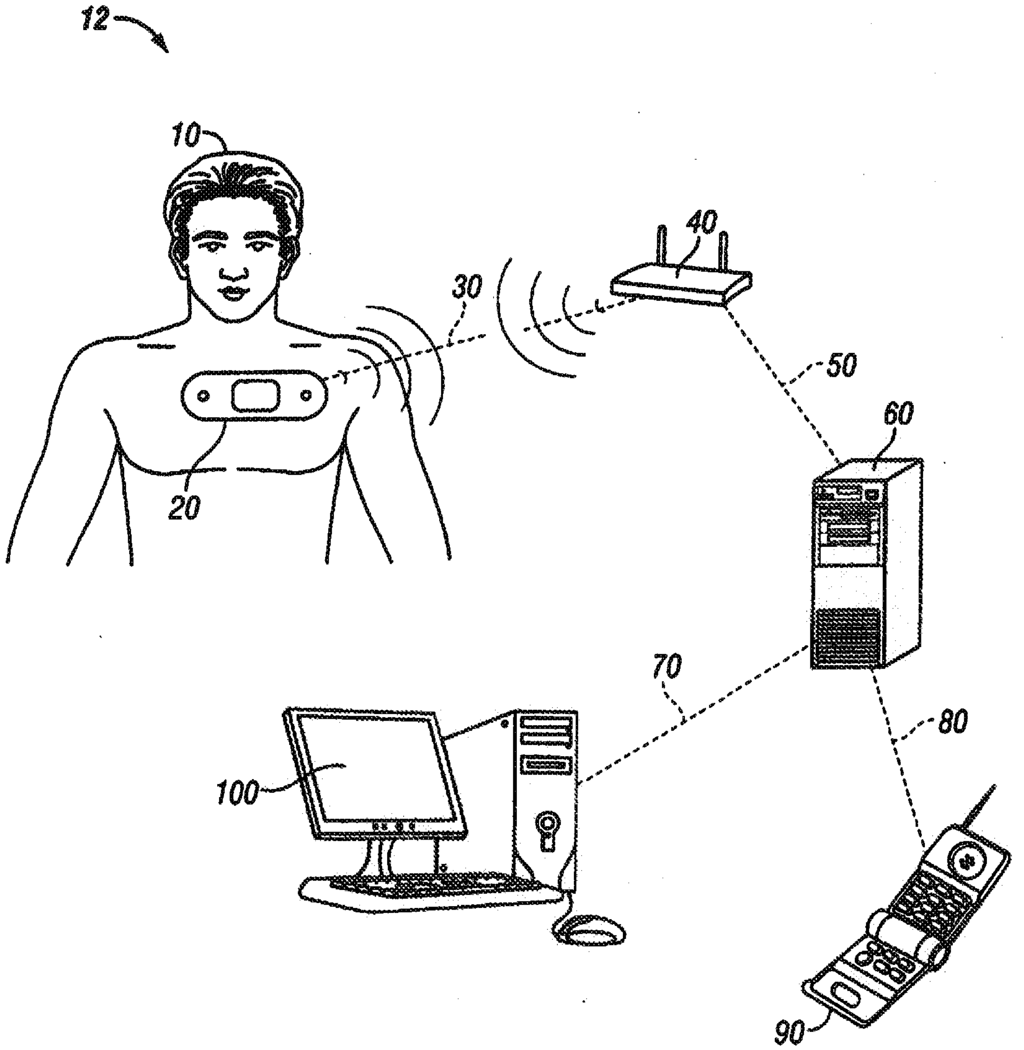
(57) **ABSTRACT**

Systems and methods of tracking a patient within a facility via a vital-signs patch attached to the patient are disclosed. A first signal is received from a bridge, the first signal comprising information indicative of a vital-signs patch attached to a patient. The patient is identified based at least in part on the information. Location of the patient is determined based on a known location of the bridge within the facility.



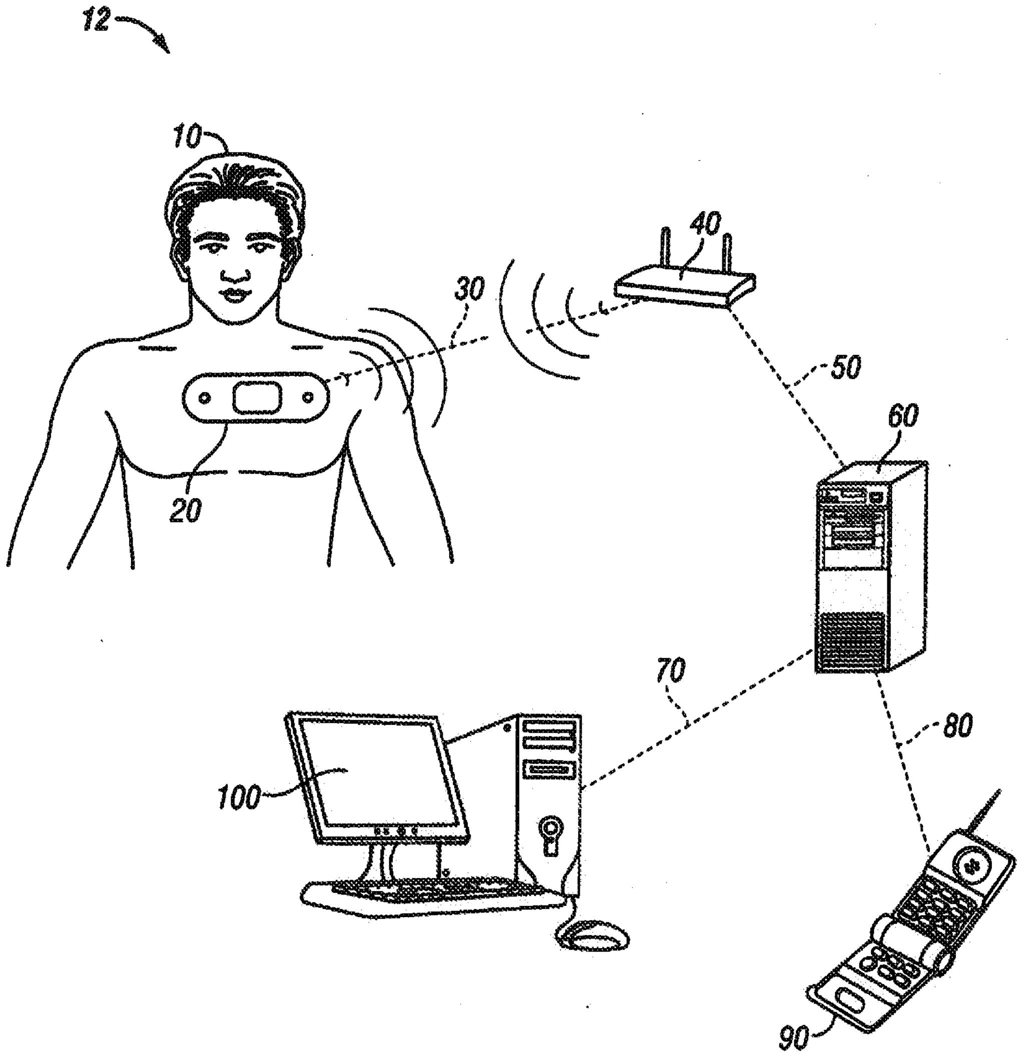


FIG. 1

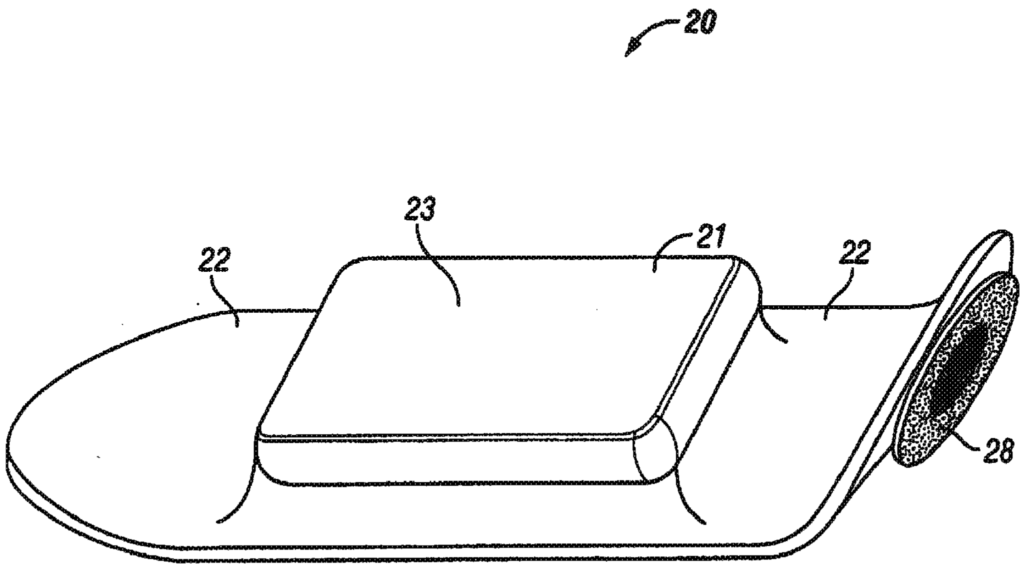


FIG. 2A

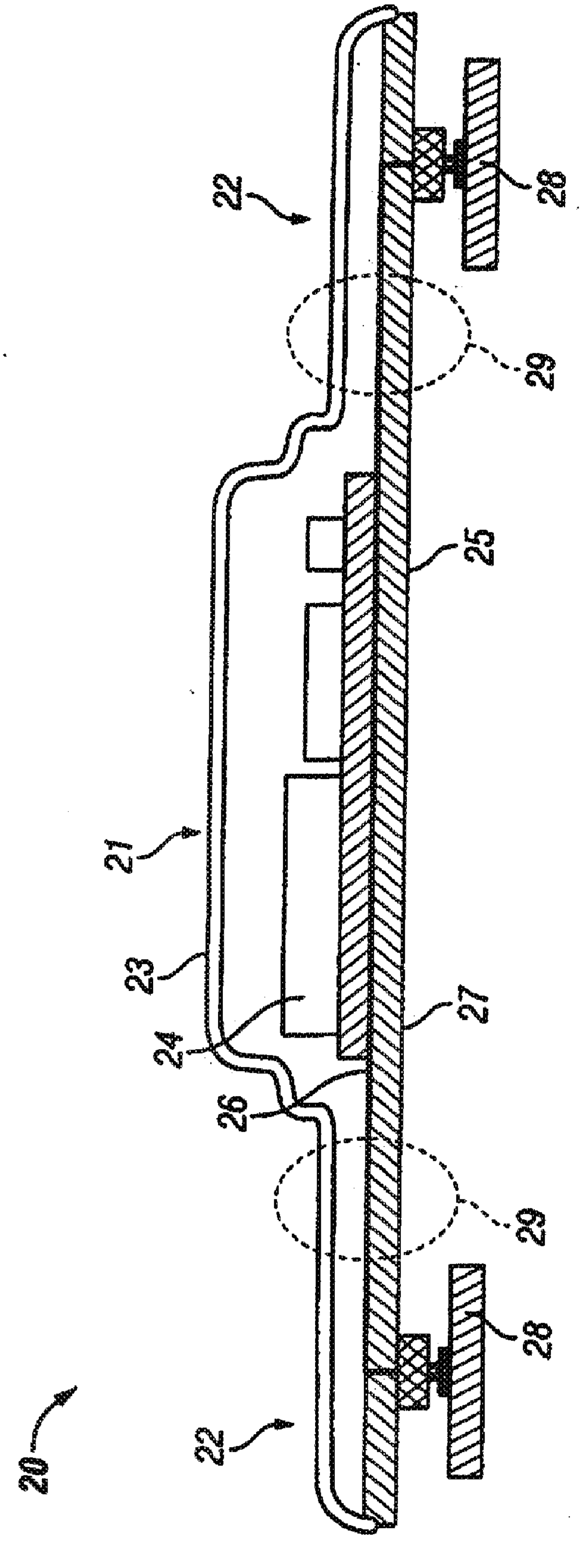


FIG. 2B

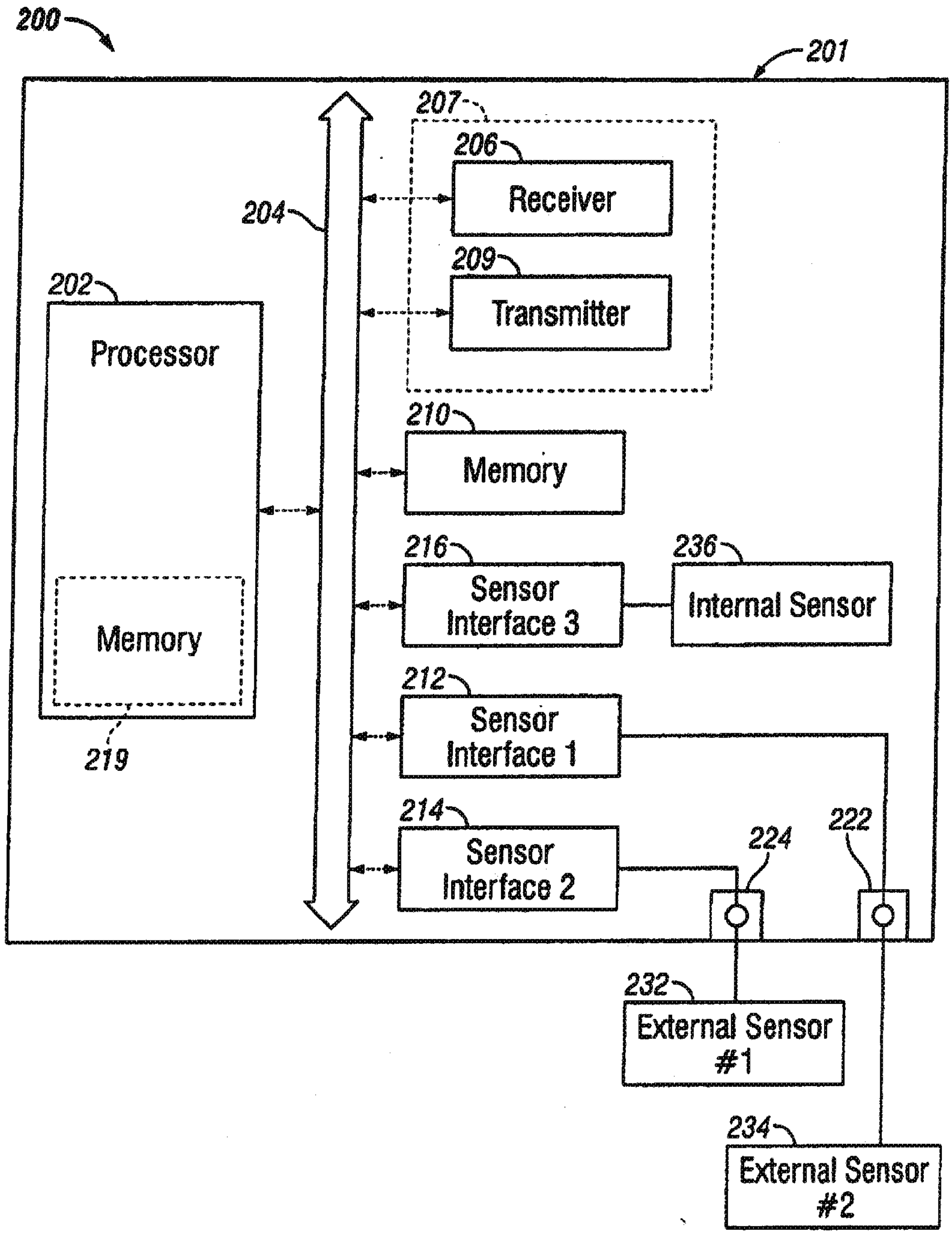

200
201
207
206
Receiver
209
Transmitter
204
202
Processor
210
Memory
216
Sensor Interface 3
236
Internal Sensor
Memory
219
212
Sensor Interface 1
214
Sensor Interface 2
224
222
232
External Sensor #1
234
External Sensor #2

FIG. 2C

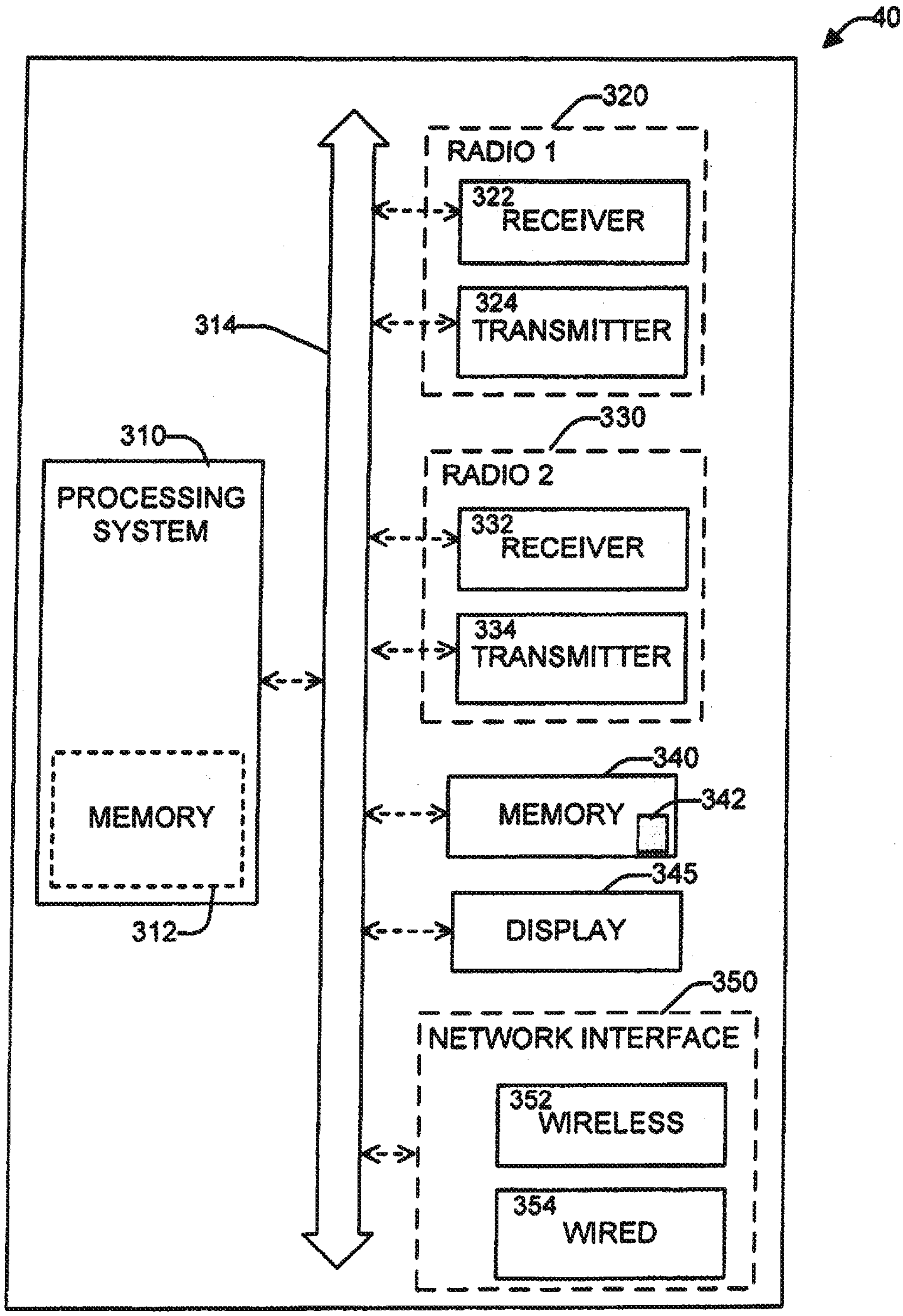

40
320
RADIO 1
322
RECEIVER
324
TRANSMITTER
314
330
RADIO 2
332
RECEIVER
334
TRANSMITTER
310
PROCESSING SYSTEM
MEMORY
312
340
MEMORY
342
345
DISPLAY
350
NETWORK INTERFACE
352
WIRELESS
354
WIRED

FIG. 3A

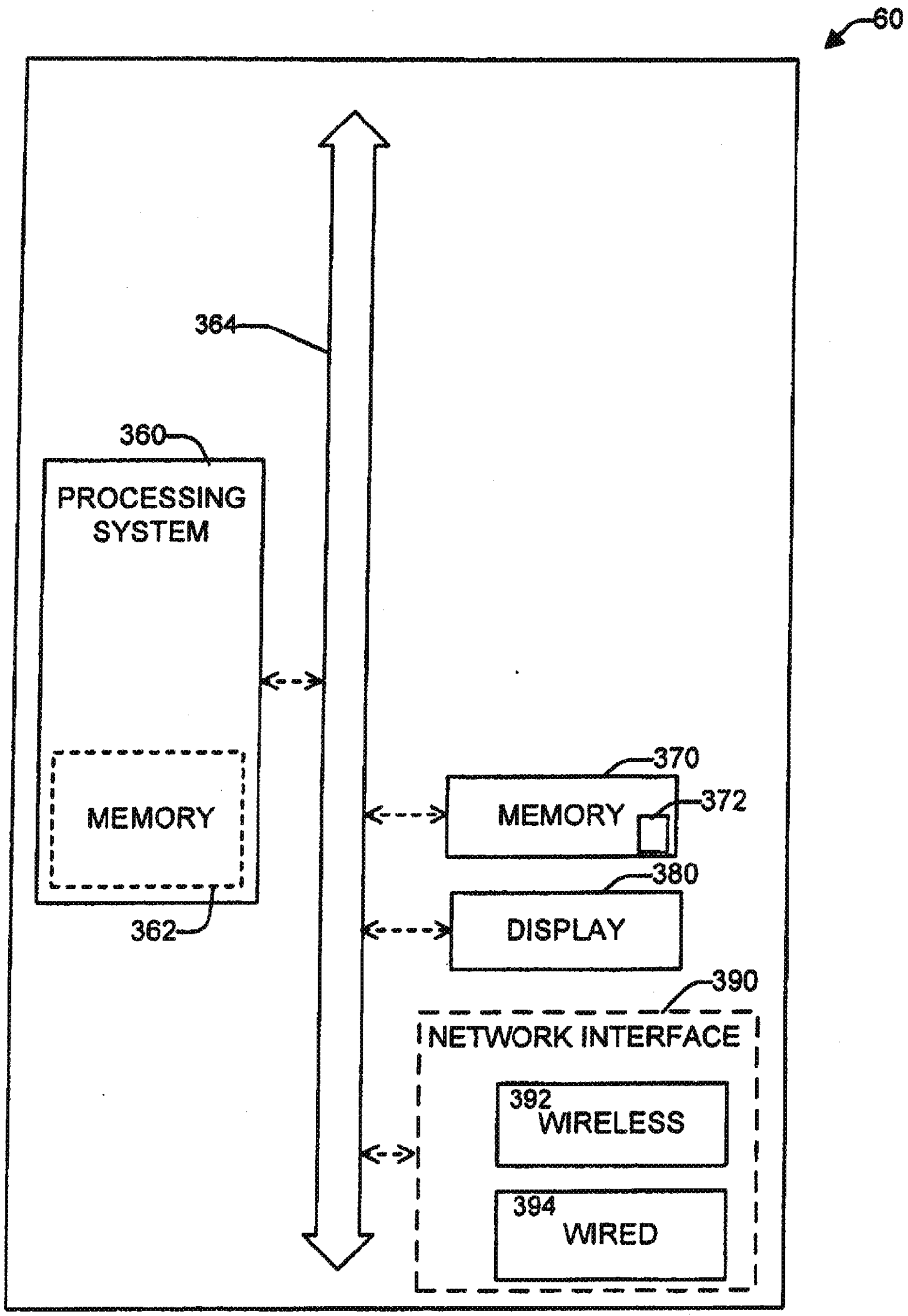

60
364
360
PROCESSING SYSTEM
MEMORY
362
370
MEMORY
372
380
DISPLAY
390
NETWORK INTERFACE
392
WIRELESS
394
WIRED

FIG. 3B

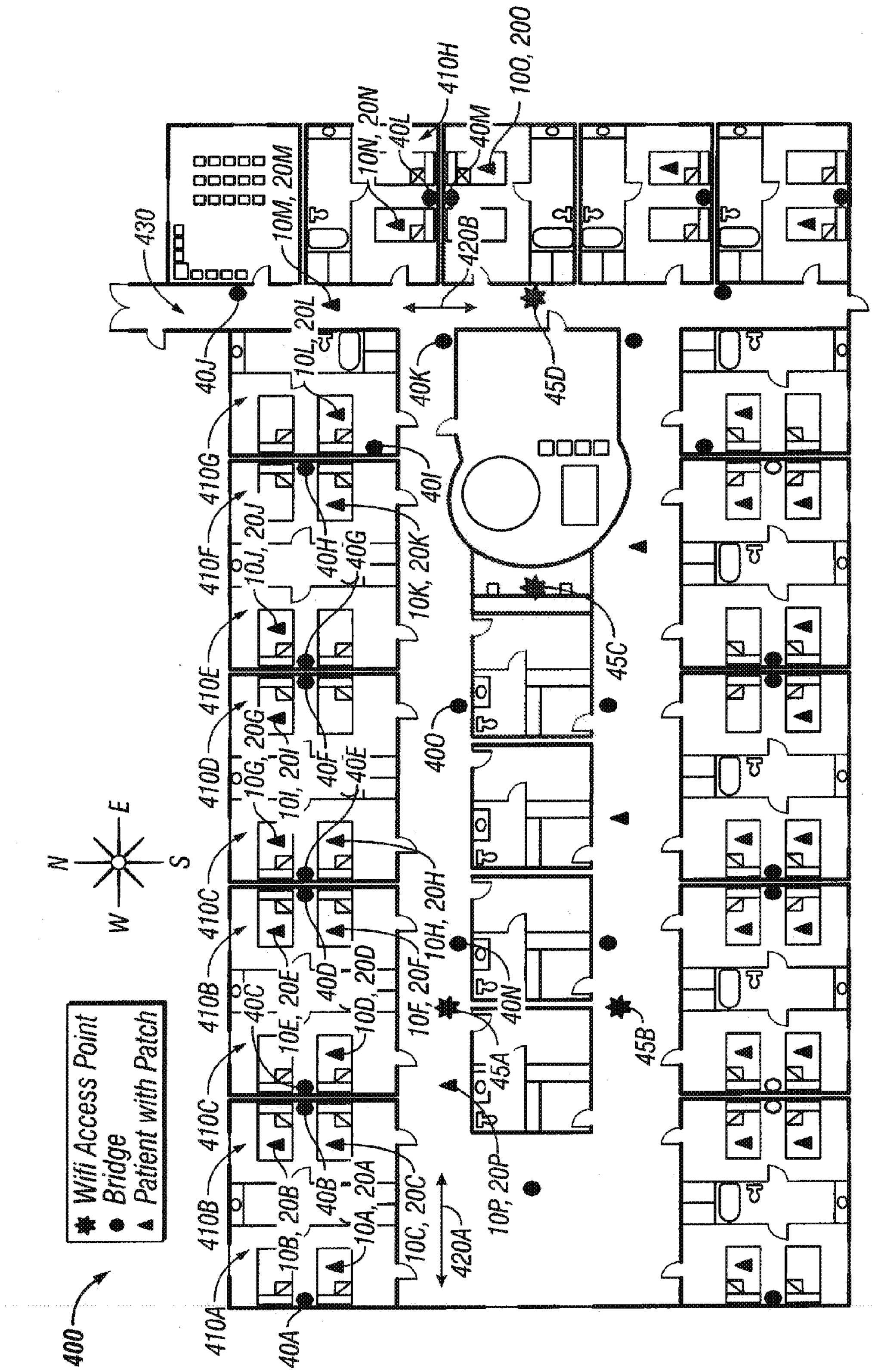

400
Wifi Access Point
Bridge
Patient with Patch
N
E
S
W
410A
410B
410C
410D
410E
410F
410G
410H
420A
420B
430
40A
40B
40C
40D
40E
40F
40G
40H
40I
40J
40K
40L
40M
40N
40O
45A
45B
45C
45D
10A, 20A
10B, 20B
10C, 20C
10D, 20D
10E, 20E
10F, 20F
10G, 20G
10H, 20H
10I, 20I
10J, 20J
10K, 20K
10L, 20L
10M, 20M
10N, 20N
10O, 20O
10P, 20P

FIG. 4A

Monitor Patch	Available Bridge	Signal Level	Selected Bridge
20A	40A	25	40A
20B	40B	27	40B
	40C	20	
20C	40B	22	40B
	40C	19	
20D	40B	18	40C
	40C	23	
20E	40D	21	40D
	40E	18	
20F	40D	20	40D
	40E	16	
	40N	13	
20G	40D	16	40E
	40E	22	
20H	40D	14	40F
	40E	20	
20I	40F	28	40F
	40G	19	
20J	40F	19	40G
	40G	27	
20K	40H	26	40H
	40I	20	
20L	40H	17	40I
	40I	29	
20M	40I	15	40J
	40J	19	
	40K	17	
20N	40L	28	40L
	40M	15	
20O	40L	18	40M
	40M	27	
20P	40C	13	40N
	40N	20	

FIG. 4B

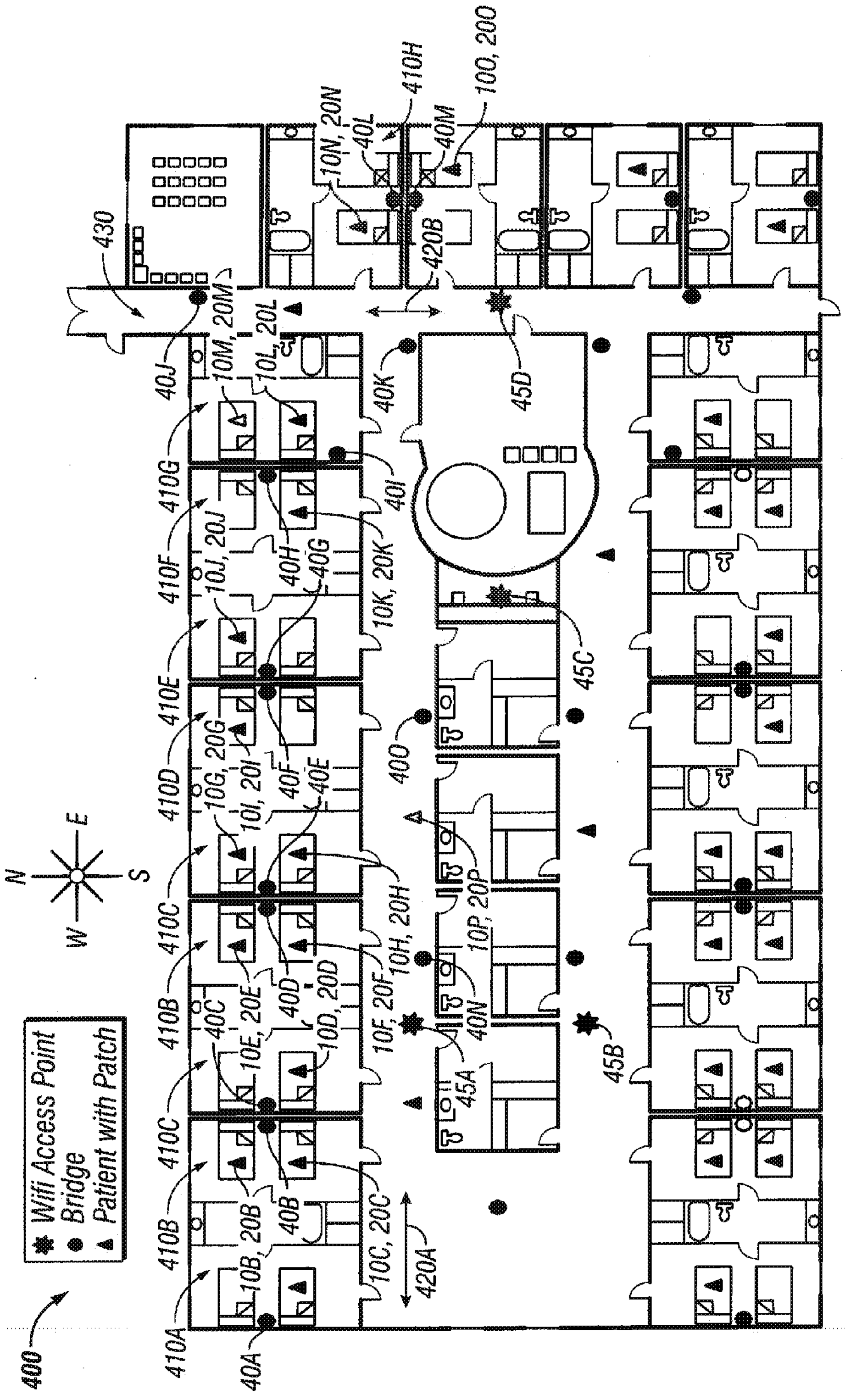

400
Wifi Access Point
Bridge
Patient with Patch
N
E
S
W
410A
410B
410C
410D
410E
410F
410G
410H
420A
420B
430
40A
40B
40C
40D
40E
40F
40G
40H
40I
40J
40K
40L
40M
40N
45A
45B
45C
45D
10B, 20B
10C, 20C
10D, 20D
10E, 20E
10F, 20F
10G, 20G
10H, 20H
10I, 20I
10J, 20J
10K, 20K
10L, 20L
10M, 20M
10N, 20N
10O, 20O
10P, 20P

FIG. 5A

Monitor Patch	Available Bridge	Signal Level	Selected Bridge
20A	N/A	N/A	N/A
20B	40B	27	40B
	40C	20	
20C	40B	22	40B
	40C	19	
20D	40B	18	40C
	40C	23	
20E	40D	21	40D
	40E	18	
20F	40D	20	40D
	40E	16	
	40N	13	
20G	40D	16	40E
	40E	22	
20H	40D	14	40F
	40E	20	
20I	40F	28	40F
	40G	19	
20J	40F	19	40G
	40G	27	
20K	40H	26	40H
	40I	20	
20L	40H	17	40I
	40I	29	
20M	40H	14	40I
	40I	20	
20N	40L	28	40L
	40M	15	
20O	40L	18	40M
	40M	27	
20P	40N	19	40O
	40O	17	

FIG. 5B

610A

Linkable Patches	Signal Level	Associated Patches
20A	25	20A

620A

Linkable Patches	Signal Level	Associated Patches
N/A	N/A	N/A

FIG. 6A

610B

Linkable Patches	Signal Level	Associated Patches
20K	20	20L
20L	29	

620B

Linkable Patches	Signal Level	Associated Patches
20K	20	20L
20L	29	20M
20M	20	

FIG. 6B

610C

Linkable Patches	Signal Level	Associated Patches
20F	13	20P
20P	20	

620C

Linkable Patches	Signal Level	Associated Patches
20F	13	N/A
20P	19	

FIG. 6C

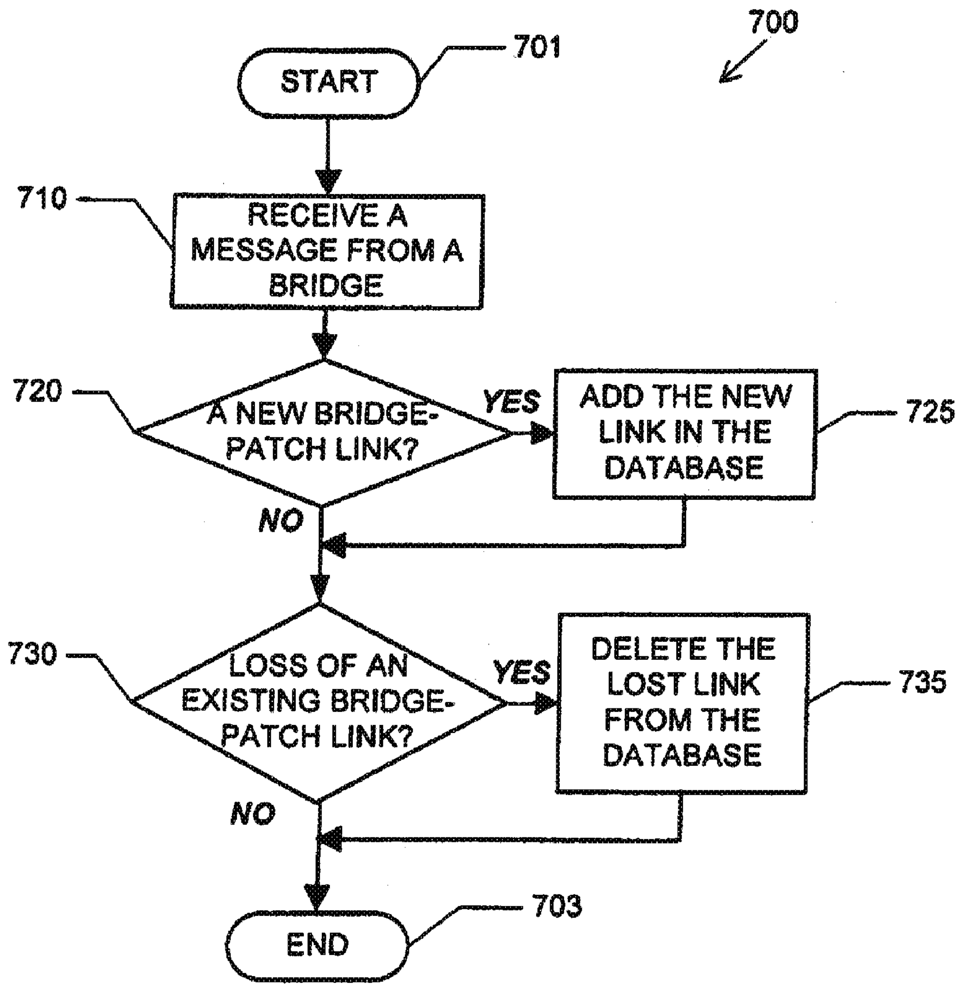

700
START
701
710
RECEIVE A MESSAGE FROM A BRIDGE
720
A NEW BRIDGE-PATCH LINK?
YES
ADD THE NEW LINK IN THE DATABASE
725
NO
730
LOSS OF AN EXISTING BRIDGE-PATCH LINK?
YES
DELETE THE LOST LINK FROM THE DATABASE
735
NO
END
703

FIG. 7

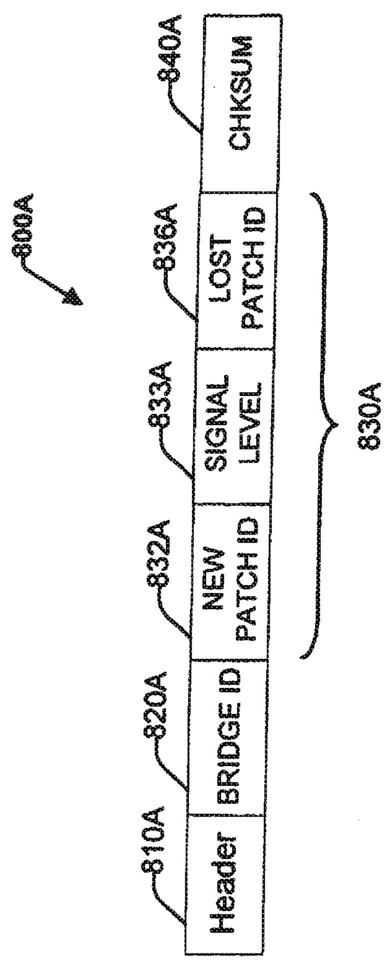

800A
810A
Header
820A
BRIDGE ID
832A
NEW PATCH ID
833A
SIGNAL LEVEL
836A
LOST PATCH ID
840A
CHKSUM
830A

FIG. 8A

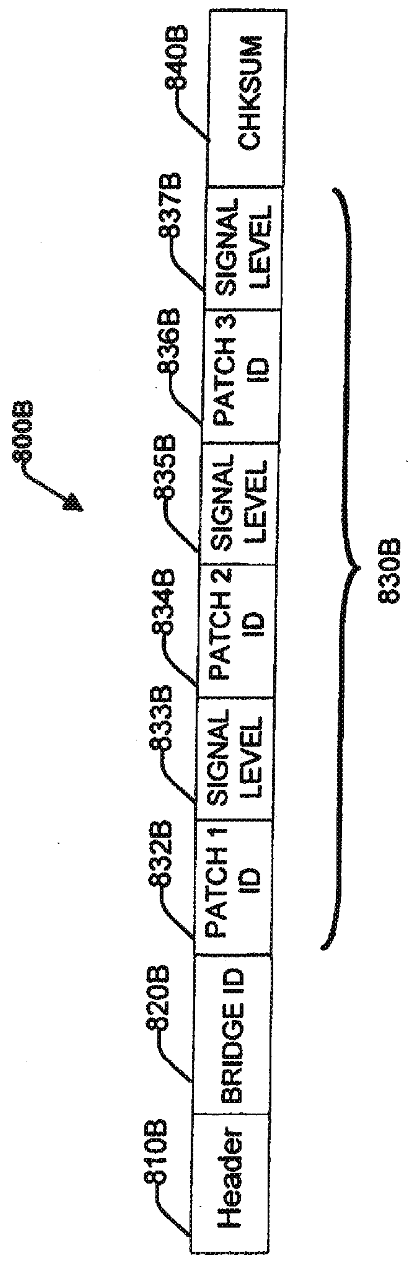

800B
810B
Header
820B
BRIDGE ID
832B
PATCH 1 ID
833B
SIGNAL LEVEL
834B
PATCH 2 ID
835B
SIGNAL LEVEL
836B
PATCH 3 ID
837B
SIGNAL LEVEL
840B
CHKSUM
830B

FIG. 8B

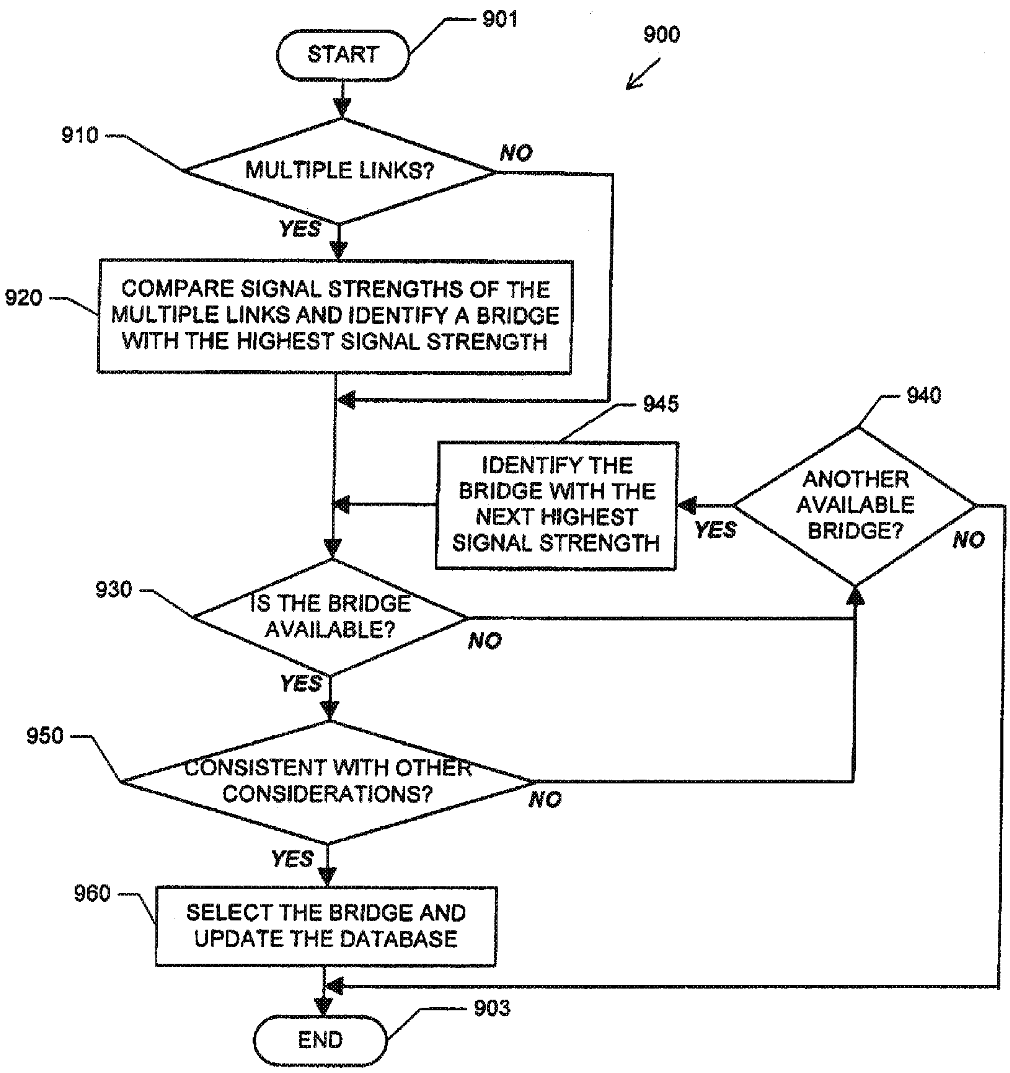

901
900
START
910
MULTIPLE LINKS?
NO
YES
920
COMPARE SIGNAL STRENGTHS OF THE MULTIPLE LINKS AND IDENTIFY A BRIDGE WITH THE HIGHEST SIGNAL STRENGTH
945
940
IDENTIFY THE BRIDGE WITH THE NEXT HIGHEST SIGNAL STRENGTH
ANOTHER AVAILABLE BRIDGE?
YES
NO
930
IS THE BRIDGE AVAILABLE?
NO
YES
950
CONSISTENT WITH OTHER CONSIDERATIONS?
NO
YES
960
SELECT THE BRIDGE AND UPDATE THE DATABASE
903
END

FIG. 9

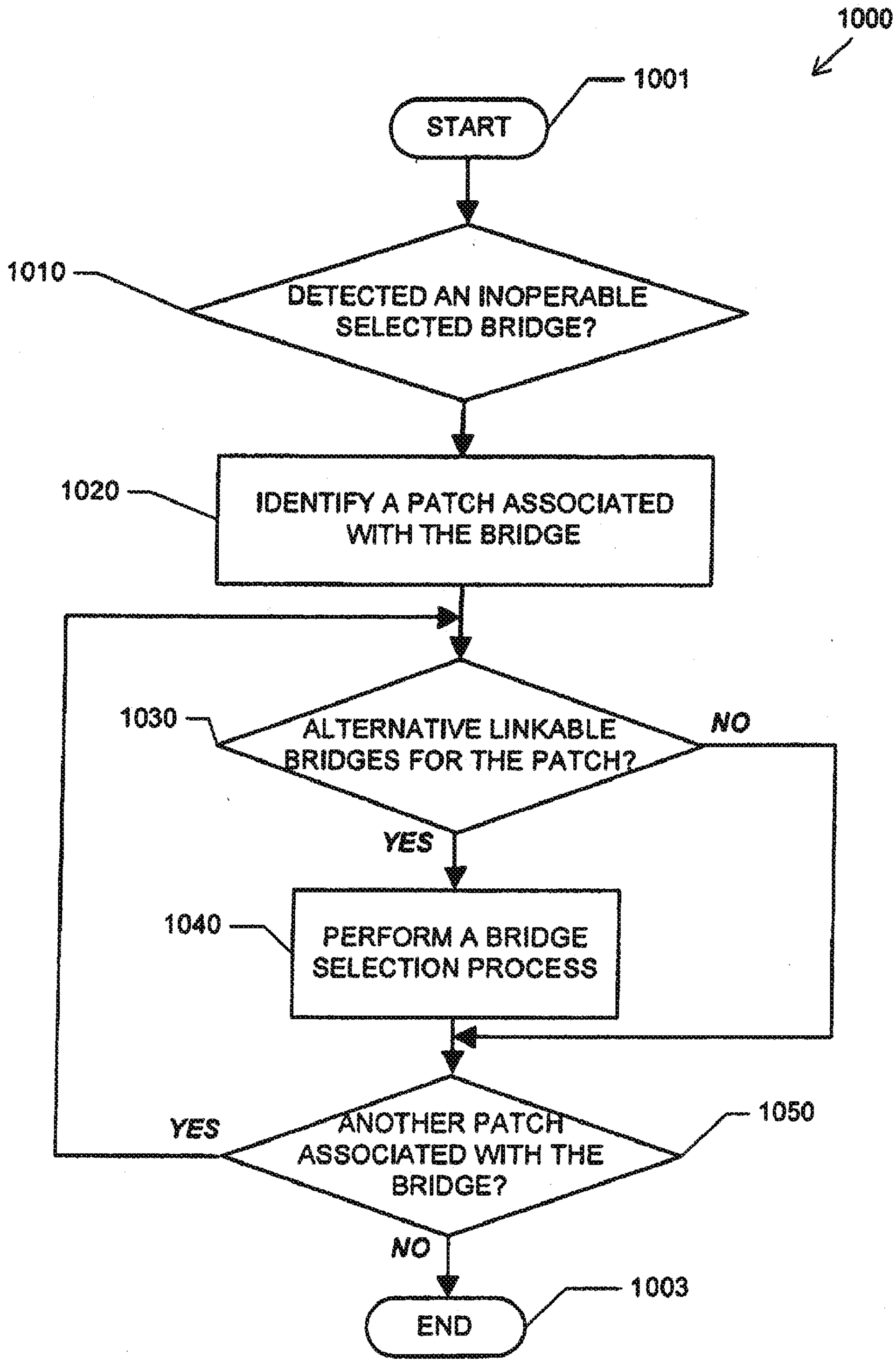

1000
1001
START
1010
DETECTED AN INOPERABLE SELECTED BRIDGE?
1020
IDENTIFY A PATCH ASSOCIATED WITH THE BRIDGE
1030
ALTERNATIVE LINKABLE BRIDGES FOR THE PATCH?
NO
YES
1040
PERFORM A BRIDGE SELECTION PROCESS
YES
ANOTHER PATCH ASSOCIATED WITH THE BRIDGE?
1050
NO
1003
END

FIG. 10

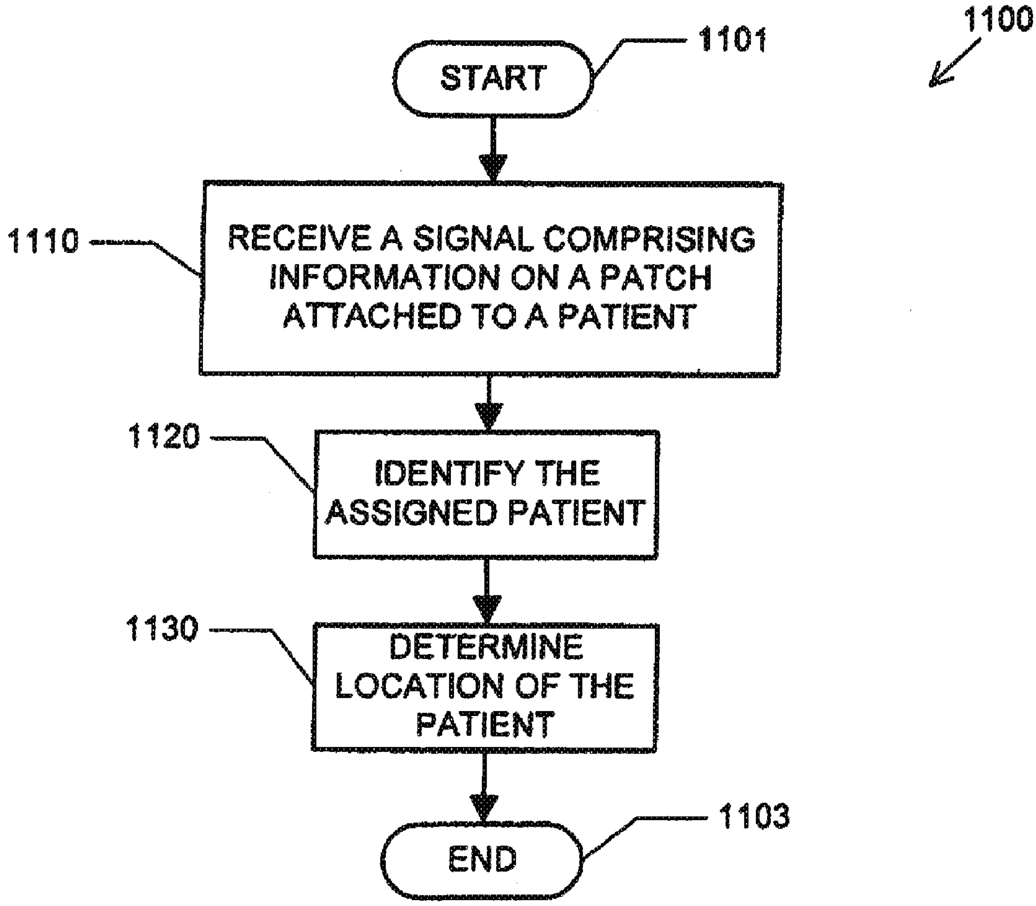

1100
START
1101
RECEIVE A SIGNAL COMPRISING INFORMATION ON A PATCH ATTACHED TO A PATIENT
1110
IDENTIFY THE ASSIGNED PATIENT
1120
DETERMINE LOCATION OF THE PATIENT
1130
END
1103

FIG. 11

Monitor Patch	Patient ID	Assigned Patient
20A	10A	Kathy Jones
20B	10B	John Doe
20C	10C	Bob Chang
...	...	...
20O	10O	Jose Rodriguez

FIG. 12A

Bridge	Location
40A	Room 1
40B	Room 2
40C	Room 3
40D	Room 4
40E	Room 5
40F	Room 6
40G	Room 7
40H	Room 8
40I	Room 9
40J	Hallway 1 Sec1
40K	Hallway 2 Sec 4
40L	Room 9
40M	Room 10
40N	Hallway 2 Sec 2
40O	Hallway 2 Sec 3

FIG. 12B

SYSTEM AND METHOD FOR LOCATION TRACKING OF PATIENTS IN A VITAL-SIGNS MONITOR SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] The following applications disclose certain common subject matter with the present application: A Vital-Signs Monitor with Encapsulation Arrangement, docket number 080624-0612; A Vital-Signs Monitor with Spaced Electrodes, docket number 080624-0623; A Vital-Signs Patch Having a Strain Relief, docket number 080624-0624; A Temperature Probe Suitable for Axillary Reading, docket number 080624-0625; System and Method for Monitoring Body Temperature of a Person, docket number 080624-0626; A System and Method for Storing and Forwarding Data from a Vital-Signs Monitor, docket number 080624-0627; System and Method for Saving Battery Power in a Vital Signs Monitor, docket number 080624-0628; A System and Method for Conserving Battery Power in a Patient Monitoring System, docket number 080624-0629; A System and Method for Saving Battery Power in a Patient Monitoring System, docket number 080624-0630; A System And Method for Tracking Vital-Signs Monitor Patches, Docket Number 080624-0631; A System And Method for Reducing False Alarms Associated with Vital-Signs Monitoring, docket number 080624-0632; A System And Method for Reducing False Alarms Based on Motion and Location Sensing, docket number 080624-0634; all of the listed applications filed on ______.

FIELD

[0002] The present disclosure generally relates to systems and methods of physiological monitoring, and, in particular, relates to a system and method for location tracking of patients in a vita-signs monitor system.

DESCRIPTION OF THE RELATED ART

[0003] Some of the most basic indicators of a person's health are those physiological measurements that reflect basic body functions and are commonly referred to as a person's "vital signs." The four measurements commonly considered to be vital signs are body temperature, pulse rate, blood pressure, and respiratory rate. Some clinicians consider oxygen saturation (S_{02}) to be a "fifth vital sign" particularly for pediatric or geriatric cases. Some or all of these measurements may be performed routinely upon a patient when they arrive at a healthcare facility, whether it is a routine visit to their doctor or arrival at an Emergency Room (ER).

[0004] Vital signs are frequently taken by a nurse using basic tools including a thermometer to measure body temperature, a sphygmomanometer to measure blood pressure, and a watch to count the number of breaths or the number of heart beats in a defined period of time which is then converted to a "per minute" rate. If a patient's pulse is weak, it may not be possible to detect a pulse by hand and the nurse may use a stethoscope to amplify the sound of the patient's heart beat so that she can count the beats. Oxygen saturation of the blood is most easily measured with a pulse oximeter.

[0005] When a patient is admitted to a hospital, it is common for vital signs to be measured and recorded at regular intervals during the patient's stay to monitor their condition. A typical interval is 4 hours, which leads to the undesirable requirement for a nurse to awaken a patient in the middle of the night to take vital sign measurements.

[0006] When a patient is admitted to an ER, it is common for a nurse to do a "triage" assessment of the patient's condition that will determine how quickly the patient receives treatment. During busy times in an ER, a patient who does not appear to have a life-threatening injury may wait for hours until more-serious cases have been treated. While the patient may be reassessed at intervals while awaiting treatment, the patient may not be under observation between these reassessments.

[0007] Measuring certain vital signs is normally intrusive at best and difficult to do on a continuous basis. Measurement of body temperature, for example, is commonly done by placing an oral thermometer under the tongue or placing an infrared thermometer in the ear canal such that the tympanic membrane, which shared blood circulation with the brain, is in the sensor's field of view. Another method of taking a body temperature is by placing a thermometer under the arm, referred to as an "axillary" measurement as axilla is the Latin word for armpit. Skin temperature can be measured using a stick-on strip that may contain panels that change color to indicate the temperature of the skin below the strip.

[0008] Measurement of respiration is easy for a nurse to do, but relatively complicated for equipment to achieve. A method of automatically measuring respiration is to encircle the upper torso with a flexible band that can detect the physical expansion of the rib cage when a patient inhales. An alternate technique is to measure a high-frequency electrical impedance between two electrodes placed on the torso and detect the change in impedance created when the lungs fill with air. The electrodes are typically placed on opposite sides of one or both lungs, resulting in placement on the front and back or on the left and right sides of the torso, commonly done with adhesive electrodes connected by wires or by using a torso band with multiple electrodes in the strap.

[0009] Measurement of pulse is also relatively easy for a nurse to do and intrusive for equipment to achieve. A common automatic method of measuring a pulse is to use an electrocardiograph (ECG or EKG) to detect the electrical activity of the heart. An EKG machine may use 12 electrodes placed at defined points on the body to detect various signals associated with the heart function. Another common piece of equipment is simply called a "heart rate monitor." Widely sold for use in exercise and training, heart rate monitors commonly consist of a torso band, in which are embedded two electrodes held against the skin and a small electronics package. Such heart rate monitors can communicate wirelessly to other equipment such as a small device that is worn like a wristwatch and that can transfer data wirelessly to a PC.

[0010] Nurses are expected to provide complete care to an assigned number of patients. The workload of a typical nurse is increasing, driven by a combination of a continuing shortage of nurses, an increase in the number of formal procedures that must be followed, and an expectation of increased documentation. Replacing the manual measurement and logging of vital signs with a system that measures and records vital signs would enable a nurse to spend more time on other activities and avoid the potential for error that is inherent in any manual procedure.

SUMMARY

[0011] For some or all of the reasons listed above, there is a need to be able to continuously monitor patients in different settings. In addition, it is desirable for this monitoring to be done with limited interference with a patient's mobility or interfering with their other activities.

[0012] Embodiments of the patient monitoring system disclosed herein measure certain vital signs of a patient, which include respiratory rate, pulse rate, blood pressure, body temperature, and, in some cases, oxygen saturation (S_{O2}), on a regular basis and compare these measurements to defined limits.

[0013] In one aspect of the present disclosure, a method of tracking a patient within a facility via a vital-signs patch attached to the patient is provided. The method can comprise receiving a first signal from a bridge, the first signal comprising information indicative of a vital-signs patch attached to a patient. The method can comprise identifying the patient based at least in part on the information. The method can comprise determining location of the patient based on a known location of the bridge within the facility.

[0014] In one aspect of the present disclosure, a vital-sign monitoring system is provided. The system can comprise a plurality of vital-sign monitor patches configured to monitor one or more vital-signs of patients to whom the vital-sign monitor patches are attached. The system can further comprise a surveillance server configured to collect data relating to the one or more vital-signs of the patients from the plurality of vital-sign monitor patches. The system can further comprise a plurality of bridges at respective locations within a facility and configured to provide data connections between the plurality of vital-sign monitor patches and the surveillance server. The surveillance server can be configured to: receive a first signal from a bridge in the monitoring network, the first signal comprising information indicative of a vital-sign monitor patch attached to a patient; identify a patient based at least in part on the first signal; and determine location of the patient based on a known location of the bridge within the facility.

[0015] It is understood that other configurations of the subject technology will become readily apparent to those skilled in the art from the following detailed description, wherein various configurations of the subject technology are shown and described by way of illustration. As will be realized, the subject technology is capable of other and different configurations and its several details are capable of modification in various other respects, all without departing from the scope of the subject technology. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The accompanying drawings, which are included to provide further understanding and are incorporated in and constitute a part of this specification, illustrate disclosed embodiments and together with the description serve to explain the principles of the disclosed embodiments. In the drawings:

[0017] FIG. **1** is a diagram illustrating an exemplary embodiment of a patient monitoring system according to certain aspects of the present disclosure.

[0018] FIG. **2**A is a perspective view of the vital-signs monitor patch of FIG. **1** according to certain aspects of the present disclosure.

[0019] FIG. **2**B is a cross-section of the vital-signs monitor patch of FIG. **1** according to certain aspects of the present disclosure.

[0020] FIG. **2**C is a functional block diagram illustrating exemplary electronic and sensor components of the vital-signs monitor patch of FIG. **1** according to certain aspects of the present disclosure.

[0021] FIG. **3**A is a functional schematic diagram of the bridge according to certain aspects of the subject disclosure.

[0022] FIG. **3**B is a functional schematic diagram of an embodiment of the surveillance server according to certain aspects of the present disclosure.

[0023] FIG. **4**A is a map depicting a healthcare facility (e.g., a hospital) **400** in which a patient monitoring system such as the one shown in FIG. **1** is implemented according to certain aspects of the present disclosure.

[0024] FIG. **4**B is a portion of an exemplary database comprising monitor patches, their linkable bridges, signal levels associated with the communication links between the monitor patches and the linkable bridges, and selected bridges according to certain aspects of the present disclosure.

[0025] FIG. **5**A is a map of the healthcare facility depicted in FIG. **4**A after a passage of time.

[0026] FIG. **5**B is a portion of an updated version of the database shown in FIG. **4**B according to certain embodiments of the present disclosure.

[0027] FIGS. **6**A-C show a first set of lists stored in various bridge at the time of FIG. **4**A, and a second set of lists which corresponds to updated lists stored in the bridges at the time of FIG. **5**A.

[0028] FIG. **7** is a flowchart illustrating a process for tracking locations of monitor patches by keeping and updating a database comprising information indicative of the monitor patches and their linkable and selected bridges according to certain aspects of the present disclosure.

[0029] FIG. **8**A is a diagram illustrating an exemplary data structure for a message indicating a new communication link and/or loss of an existing communication link according to certain aspects of the present disclosure.

[0030] FIG. **8**B is a diagram illustrating an exemplary data structure for an alternative message indicating a new communication link and/or loss of an existing communication link according to alternative aspects of the present disclosure.

[0031] FIG. **9** is a flowchart illustrating an exemplary process for a bridge selection process according to certain aspects of the present disclosure.

[0032] FIG. **10** is a flowchart illustrating a process for detecting an inoperable bridge and selecting an alternative bridge to replace the inoperable bridge for the monitor patches that were previously associated with the inoperable bridge according to certain aspects of the present disclosure.

[0033] FIG. **11** is a flowchart illustrating a process for determining locations of patients in a healthcare facility according to certain aspects of the present disclosure.

[0034] FIG. **12**A is an exemplary database comprising monitor patches, IDs of patients assigned to the monitor patches, and names of assigned patients according to certain aspects of the present disclosure.

[0035] FIG. **12**B is an exemplary database comprising bridges and their respective locations within the healthcare facility according to certain aspects of the present disclosure.

DETAILED DESCRIPTION

[0036] Periodic monitoring of patients in a hospital is desirable at least to ensure that patients do not suffer an un-noticed sudden deterioration in their condition or a secondary injury during their stay in the hospital. It is impractical to provide continuous monitoring by a clinician and cumbersome to connect sensors to a patient, which are then connected to a fixed monitoring instrument by wires. Furthermore, systems that sound an alarm when the measured value exceeds a threshold value may sound alarms so often and in situations that are not truly serious that such alarms are ignored by clinicians.

[0037] Measuring vital signs is difficult to do on a continuous basis. Accurate measurement of cardiac pulse, for example, can be done using an electrocardiograph (ECG or EKG) to detect the electrical activity of the heart. An EKG machine may use up to 12 electrodes placed at various points on the body to detect various signals associated with the cardiac function. Another common piece of equipment is termed a "heart rate monitor." Widely sold for use in exercise and physical training, heart rate monitors may comprise a torso band in which are embedded two electrodes held against the skin and a small electronics package. Such heart rate monitors can communicate wire lessly to other equipment such as a small device that is worn like a wristwatch and that can transfer data wirelessly to a personal computer (PC).

[0038] Monitoring of patients that is referred to as "continuous" is frequently periodic, in that measurements are taken at intervals. In many cases, the process to make a single measurement takes a certain amount of time, such that even back-to-back measurements produce values at an interval equal to the time that it takes to make the measurement. For the purpose of vital sign measurement, a sequence of repeated measurements can be considered to be "continuous" when the vital sign is not likely to change an amount that is of clinical significance within the interval between measurements. For example, a measurement of blood pressure every 10 minutes may be considered "continuous" if it is considered unlikely that a patient's blood pressure can change by a clinically significant amount within 10 minutes. The interval appropriate for measurements to be considered continuous may depend on a variety of factors including the type of injury or treatment and the patient's medical history. Compared to intervals of 4-8 hours for manual vital sign measurement in a hospital, measurement intervals of 30 minutes to several hours may still be considered "continuous."

[0039] Certain exemplary embodiments of the present disclosure include a system that comprises a vital-signs monitor patch that is attached to the patient, and a bridge that communicates with monitor patches and links them to a central server that processes the data, where the server can send data and alarms to a hospital system according to algorithms and protocols defined by the hospital.

[0040] The construction of the vital-signs monitor patch is described according to certain aspects of the present disclosure. As the patch may be worn continuously for a period of time that may be several days, as is described in the following disclosure, it is desirable to encapsulate the components of the patch such that the patient can bathe or shower and engage in their normal activities without degradation of the patch function. An exemplary configuration of the construction of the patch to provide a hermetically sealed enclosure about the electronics is disclosed.

[0041] In the following detailed description, numerous specific details are set forth to provide a full understanding of the present disclosure. It will be apparent, however, to one ordinarily skilled in the art that embodiments of the present disclosure may be practiced without some of the specific details. In other instances, well-known structures and techniques have not been shown in detail so as not to obscure the disclosure.

[0042] FIG. **1** discloses a vital sign monitoring system according to certain embodiments of the present disclosure. The vital sign monitoring system **12** includes vital-signs monitor patch **20**, bridge **40**, and surveillance server **60** that can send messages or interact with peripheral devices exemplified by mobile device **90** and workstation **100**.

[0043] Monitor patch **20** resembles a large adhesive bandage and is applied to a patient **10** when in use. It is preferable to apply the monitor patch **20** to the upper chest of the patient **10** although other locations may be appropriate in some circumstances. Monitor patch **20** incorporates one or more electrodes (not shown) that are in contact with the skin of patient **10** to measure vital signs such as cardiac pulse rate and respiration rate. Monitor patch **20** also may include other sensors such as an accelerometer, temperature sensor, or oxygen saturation sensor to measure other characteristics associated with the patient. These other sensors may be internal to the monitor patch **20** or external sensors that are operably connected to the monitor patch **20** via a cable or wireless connection. Monitor patch **20** also includes a wireless transmitter that can both transmit and receive signals. This transmitter is preferably a short-range, low-power radio frequency (RF) device operating in one of the unlicensed radio bands. One band in the United States (US) is, for example, centered at 915 MHz and designated for industrial, scientific and medical (ISM) purposes. An example of an equivalent band in the European Union (EU) is centered at 868 MHz. Other frequencies of operation may be possible dependent upon the International Telecommunication Union (ITU), local regulations and interference from other wireless devices.

[0044] Surveillance server **60** may be a standard or virtualized computer server connected to the hospital communication network and preferably located in the hospital data center or computer room, although other locations may be employed. The server **60** stores and processes signals related to the operation of the patient monitoring system **12** disclosed herein including the association of individual monitor patches **20** with patients **10** and measurement signals received from multiple monitor patches **20**. Hence, although only a single patient **10** and monitor patch **20** are depicted in FIG. **1**, the server **60** is able to monitor the monitor patches **20** for multiple patients **10**.

[0045] Bridge **40** is a device that connects, or "bridges", between monitor patch **20** and server **60**. Bridge **40** communicates with monitor patch **20** over communication link **30** operating, in these exemplary embodiments, at approximately 915 MHz and at a power level that enables communication link **30** to function up to a distance of approximately 10 meters. It is preferable to place a bridge **40** in each room and at regular intervals along hallways of the healthcare facility where it is desired to provide the ability to communicate with monitor patches **20**. Bridge **40** also is able to communicate with server **60** over network link **50** using any of a variety of computer communication systems including hardwired and wireless Ethernet using protocols such as 802.11a/b/g or 802.3af. As the communication protocols of communication link **30** and network link **50** may be very different, bridge **40** provides data buffering and protocol conversion to enable bidirectional signal transmission between monitor patch **20** and server **60**.

[0046] While the embodiments illustrated by FIG. **1** employ a bridge **20** to provide communication link between the monitor patch **20** and the server **60**, in certain alternative embodiments, the monitor patch **20** may engage in direct wireless communication with the server **60**. In such alternative embodiments, the server **60** itself or a wireless modem connected to the server **60** may include a wireless communication system to receive data from the monitor patch **20**.

[0047] In use, a monitor patch **20** is applied to a patient **10** by a clinician when it is desirable to continuously monitor basic vital signs of patient **10** while patient **10** is, in this embodiment, in a hospital. Monitor patch **20** is intended to remain attached to patient **10** for an extended period of time, for example, up to 5 days in certain embodiments, limited by the battery life of monitor patch **20**. In some embodiments, monitor patch **20** is disposable when removed from patient **10**.

[0048] Server **60** executes analytical protocols on the measurement data that it receives from monitor patch **20** and provides this information to clinicians through external workstations **100**, preferably personal computers (PCs), laptops, or smart phones, over the hospital network **70**. Server **60** may also send messages to mobile devices **90**, such as cell phones or pagers, over a mobile device link **80** if a measurement signal exceeds specified parameters. Mobile device link **80** may include the hospital network **70** and internal or external wireless communication systems that are capable of sending messages that can be received by mobile devices **90**.

[0049] FIG. **2**A is a perspective view of the vital-signs monitor patch **20** shown in FIG. **1** according to certain aspects of the present disclosure. In the illustrated embodiment, the monitor patch **20** includes component carrier **23** comprising a central segment **21** and side segments **22** on opposing sides of the central segment **21**. In certain embodiments, the central segment **21** is substantially rigid and includes a circuit assembly (**24**, FIG. **2**B) having electronic components and battery mounted to a rigid printed circuit board (PCB). The side segments **22** are flexible and include a flexible conductive circuit (**26**, FIG. **2**B) that connect the circuit assembly **24** to electrodes **28** disposed at each end of the monitor patch **20**, with side segment **22** on the right shown as being bent upwards for purposes of illustration to make one of the electrodes **28** visible in this view.

[0050] FIG. **2**B is a cross-sectional view of the vital-signs patch **20** shown in FIGS. **1** and **2**A according to certain aspects of the present disclosure. The circuit assembly **24** and flexible conductive circuit **26** described above can be seen herein. The flexible conductive circuit **26** operably connects the circuit assembly **24** to the electrodes **28**. Top and bottom layers **23** and **27** form a housing **25** that encapsulate circuit assembly **28** to provide a water and particulate barrier as well as mechanical protection. There are sealing areas on layers **23** and **27** that encircles circuit assembly **28** and is visible in the cross-section view of FIG. **2**B as areas **29**. Layers **23** and **27** are sealed to each other in this area to form a substantially hermetic seal. Within the context of certain aspects of the present disclosure, the term 'hermetic' implies that the rate of transmission of moisture through the seal is substantially the same as through the material of the layers that are sealed to each other, and further implies that the size of particulates that can pass through the seal are below the size that can have a significant effect on circuit assembly **24**. Flexible conductive circuit **26** passes through portions of sealing areas **29** and the seal between layers **23** and **27** is maintained by sealing of layers **23** and **27** to flexible circuit assembly **28**. The layers **23** and **27** are thin and flexible, as is the flexible conductive circuit **26**, allowing the side segment **22** of the monitor patch **20** between the electrodes **28** and the circuit assembly **24** to bend as shown in FIG. **2**A.

[0051] FIG. **2**C is a functional block diagram **200** illustrating exemplary electronic and sensor components of the monitor patch **20** of FIG. **1** according to certain aspects of the present disclosure. The block diagram **200** shows a processing and sensor interface module **201** and external sensors **232**, **234** connected to the module **201**. In the illustrated example, the module **201** includes a processor **202**, a wireless transceiver **207** having a receiver **206** and a transmitter **209**, a memory **210**, a first sensor interface **212**, a second sensor interface **214**, a third sensor interface **216**, and an internal sensor **236** connected to the third sensor interface **216**. The first and second sensor interfaces **212** and **214** are connected to the first and second external sensors **232**, **234** via first and second connection ports **222**, **224**, respectively. In certain embodiments, some or all of the aforementioned components of the module **201** and other components are mounted on a PCB.

[0052] Each of the sensor interfaces **212**, **214**, **216** can include one or more electronic components that are configured to generate an excitation signal or provide DC power for the sensor that the interface is connected to and/or to condition and digitize a sensor signal from the sensor. For example, the sensor interface can include a signal generator for generating an excitation signal or a voltage regulator for providing power to the sensor. The sensor interface can further include an amplifier for amplifying a sensor signal from the sensor and an analog-to-digital converter for digitizing the amplified sensor signal. The sensor interface can further include a filter (e.g., a low-pass or bandpass filter) for filtering out spurious noises (e.g., a 60 Hz noise pickup).

[0053] The processor **202** is configured to send and receive data (e.g., digitized signal or control data) to and from the sensor interfaces **212**, **214**, **216** via a bus **204**, which can be one or more wire traces on the PCB. Although a bus communication topology is used in this embodiment, some or all communication between discrete components can also be implemented as direct links without departing from the scope of the present disclosure. For example, the processor **202** may send data representative of an excitation signal to the sensor excitation signal generator inside the sensor interface and receive data representative of the sensor signal from the sensor interface, over either a bus or direct data links between processor **202** and each of sensor interface **212**, **214**, and **216**.

[0054] The processor **202** is also capable of communication with the receiver **206** and the transmitter **209** of the wireless transceiver **207** via the bus **204**. For example, the processor **202** using the transmitter and receiver **209**, **206** can transmit and receive data to and from the bridge **40**. In certain embodiments, the transmitter **209** includes one or more of a RF signal generator (e.g., an oscillator), a modulator (a mixer), and a transmitting antenna; and the receiver **206** includes a demodulator (a mixer) and a receiving antenna which may or may not be the same as the transmitting antenna. In some embodiments, the transmitter **209** may include a digital-to-analog converter configured to receive data from the processor **202** and to generate a base signal; and/or the receiver **206** may include an analog-to-digital converter configured to digitize a demodulated base signal and output a stream of digitized data to the processor **202**.

[0055] The processor **202** may include a general-purpose processor or a specific-purpose processor for executing instructions and may further include a memory **219**, such as a volatile or non-volatile memory, for storing data and/or instructions for software programs. The instructions, which may be stored in a memory **219** and/or **210**, may be executed by the processor **202** to control and manage the wireless transceiver **207**, the sensor interfaces **212**, **214**, **216**, as well as provide other communication and processing functions.

[0056] The processor **202** may be a general-purpose microprocessor, a microcontroller, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a Programmable Logic Device (PLD), a controller, a state machine, gated logic, discrete hardware components, or any other suitable device or a combination of devices that can perform calculations or other manipulations of information.

[0057] Information, such as program instructions, data representative of sensor readings, preset alarm conditions, threshold limits, may be stored in a computer or processor readable medium such as a memory internal to the processor **202** (e.g., the memory **219**) or a memory external to the processor **202** (e.g., the memory **210**), such as a Random Access Memory (RAM), a flash memory, a Read Only Memory (ROM), a Programmable Read-Only Memory (PROM), an Erasable PROM (EPROM), registers, a hard disk, a removable disk, or any other suitable storage device.

[0058] In certain embodiments, the internal sensor **236** can be one or more sensors configured to measure certain properties of the processing and sensor interface module **201**, such as a board temperature sensor thermally coupled to a PCB. In other embodiments, the internal sensor **236** can be one or more sensors configured to measure certain properties of the patient **10**, such as a motion sensor (e.g., an accelerometer) for measuring the patient's motion or position with respect to gravity.

[0059] The external sensors **232**, **234** can include sensors and sensing arrangements that are configured to produce a signal representative of one or more vital signs of the patient to which the monitor patch **20** is attached. For example, the first external sensor **232** can be a set of sensing electrodes that are affixed to an exterior surface of the monitor patch **20** and configured to be in contact with the patient for measuring the patient's respiratory rate, and the second external sensor **234** can include a temperature sensing element (e.g., a thermocouple or a thermistor or resistive thermal device (RTD)) affixed, either directly or via an interposing layer, to skin of the patient **10** for measuring the patient's body temperature. In other embodiments, one or more of the external sensors **232**, **234** or one or more additional external sensors can measure other vital signs of the patient, such as blood pressure, pulse rate, or oxygen saturation.

[0060] FIG. **3A** is a functional block diagram illustrating exemplary electronic components of bridge **40** of FIG. **1** according to one aspect of the subject disclosure. Bridge **40** includes a processor **310**, radio **320** having a receiver **322** and a transmitter **324**, radio **330** having a receiver **332** and a transmitter **334**, memory **340**, display **345**, and network interface **350** having a wireless interface **352** and a wired interface **354**. In some embodiments, some or all of the aforementioned components of module **300** may be integrated into single devices or mounted on PCBs.

[0061] Processor **310** is configured to send data to and receive data from receiver **322** and transmitter **324** of radio **320**, receiver **332** and transmitter **334** of radio **330** and wireless interface **352** and wired interface **354** of network interface **350** via bus **314**. In certain embodiments, transmitters **324** and **334** may include a radio frequency signal generator (oscillator), a modulator, and a transmitting antenna, and the receivers **322** and **332** may include a demodulator and antenna which may or may not be the same as the transmitting antenna of the radio. In some embodiments, transmitters **324** and **334** may include a digital-to-analog converter configured to convert data received from processor **310** and to generate a base signal, while receivers **322** and **332** may include analog-to-digital converters configured to convert a demodulated base signal and sent a digitized data stream to processor **310**.

[0062] Processor **310** may include a general-purpose processor or a specific-purpose processor for executing instructions and may further include a memory **312**, such as a volatile or non-volatile memory, for storing data and/or instructions for software programs. The instructions, which may be stored in memories **312** or **340**, may be executed by the processor **310** to control and manage the transceivers **320**, **330**, and **350** as well as provide other communication and processing functions.

[0063] Processor **310** may be a general-purpose microprocessor, a microcontroller, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a Programmable Logic Device (PLD), a controller, a state machine, gated logic, discrete hardware components, or any other suitable device or a combination of devices that can perform calculations- or other manipulations of information.

[0064] Information such as data representative of sensor readings may be stored in memory **312** internal to processor **310** or in memory **340** external to processor **310** which may be a Random Access Memory (RAM), flash memory, Read Only Memory (ROM), Programmable Read Only Memory (PROM), Erasable Programmable Read Only Memory (EPROM), registers, a hard disk, a removable disk, a Solid State Memory (SSD), or any other suitable storage device.

[0065] Memory **312** or **340** can also store a list or a database of established communication links and their corresponding characteristics (e.g., signal levels) between the bridge **40** and its related monitor patches **20**. In the illustrated example of FIG. 3A, the memory **340** external to the processor **310** includes such a database **342**; alternatively, the memory **312** internal to the processor **310** may include such a database.

[0066] FIG. 3B is a functional block diagram illustrating exemplary electronic components of server **60** of FIG. **1** according to one aspect of the subject disclosure. Server **60** includes a processor **360**, memory **370**, display **380**, and network interface **390** having a wireless interface **392** and a wired interface **394**. Processor **360** may include a general-purpose processor or a specific-purpose processor for executing instructions and may further include a memory **362**, such as a volatile or non-volatile memory, for storing data and/or instructions for software programs. The instructions, which may be stored in memories **362** or **370**, may be executed by the processor **360** to control and manage the wireless and wired network interfaces **392**, **394** as well as provide other communication and processing functions.

[0067] Processor **360** may be a general-purpose microprocessor, a microcontroller, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a Programmable Logic Device (PLD), a controller, a state machine, gated logic, discrete hardware components, or any other suitable device or a combination of devices that can perform calculations or other manipulations of information.

[0068] Information such as data representative of sensor readings may be stored in memory **362** internal to processor **360** or in memory **370** external to processor **360** which may be a Random Access Memory (RAM), flash memory, Read Only Memory (ROM), Programmable Read Only Memory (PROM), Erasable Programmable Read Only Memory (EPROM), registers, a hard disk, a removable disk, a Solid State Memory (SSD), or any other suitable storage device.

[0069] Memory **362** or **370** can also store a database of communication links and their corresponding characteristics (e.g., signal levels) between monitor patches **20** and bridges **40**. In the illustrated example of FIG. **3**B, the memory **370** external to the processor **360** includes such a database **372**; alternatively, the memory **362** internal to the processor **360** may include such a database.

[0070] FIG. **4**A is a map depicting an exemplary healthcare facility (e.g., a hospital) **400** in which a patient monitoring system such as shown in FIG. **1** is implemented. The healthcare facility **400** includes a plurality of patient rooms **410**A-H and hallways **420**A, **420**B. Shown in the map are a plurality of vital-sign monitor patches **20**A-O attached to their respectively assigned patients **10**A-O located in the patient rooms **410**A-H and hallways **420**A, **420**B. For ease of illustration and understanding, each patient with attached patch is represented by s triangle in FIG. **4**A. The facility **400** also includes a plurality of bridges **40**A-O located at specified locations in the facility **400** and configured to engage in wireless communication with the monitor patches **20**A-O. The bridges **40**A-O are represented bas circle icons. Although there are other patient rooms, bridges, and patients/monitor patches shown in the map, for the sake of simplicity, the following description will focus on the patient rooms **410**A-H, bridges **40**A-O and patients/monitor patches **10**A-O/**20**A-O. In the illustrated example, the bridges **40**A-O are in turn connected to WiFi access points **45**A-D (shown as "stars") that are configured to route data between the bridges **40**A-O and a surveillance server **60** (FIG. **1**).

[0071] Preferably, a bridge **40** is selected for each monitor patch **20** through which the monitor patch **20** sends and receives signals to and from the server **60** via an access point **45**A, B, C, or D. For example, the monitor patch **20**B worn by the patient **10**B in the room **410**B wirelessly transmits one or more signals comprising information indicative of his vital signs (e.g., heart rate) to the bridge **40**B. The bridge **40**B receives the signals and sends the information extracted from the signals to the access point **45** as data via either a wired or wireless connection. The access point **45**A sends the data to the surveillance server **60** via either a wired or wireless connection. As other examples, the monitor patch **20**A worn by the patient **10**A in the room **410**A sends data to the server **60** via the bridge **60**A and the access point **45**A; the monitor patch **20**P worn by the patient **10**P, walking eastward in the hallway **420**A, sends data to the server **60** via the bridge **40**N and the access point **45**A; and the monitor patch **20**M worn by the patient **10**M, walking southward in the hallway **420**B, sends data to the server **60** via the bridge **40**J and the access point **45**D.

[0072] Because a monitor patch **20** and a bridge **40** have limited wireless ranges, the monitor patch **20** is located in close proximity from the bridge **40** with which the monitor patch has a communicative association. Therefore, it is possible to track the location of a monitor patch **20** by knowing the location of the selected bridge **40**. In certain embodiments of a monitoring network of the present disclosure, the surveillance server **60** is configured to track locations of the monitor patches **20**A-O by maintaining a database comprising information indicative of monitor patches **20**A-O and their selected bridges **40**A-O. In certain embodiments, the database further comprises a list of unselected but linkable bridges with which each of the monitor patches **20**A-O is capable of engaging in a bidirectional wireless data communication.

[0073] FIG. **4**B is a portion of an exemplary database comprising the monitor patches **20**A-**20**P (first column), their linkable bridges (second column), signal levels associated with the communication links between the monitor patches and the linkable bridges (third column) in an arbitrary unit (e.g., dbm), and selected bridges (fourth column) according to certain aspects of the present disclosure. Such a database may be stored in the memory **370** (FIG. **3**B) of the server **60** as database **372**, for example. Alternatively, the database may be stored in a memory located outside the server **60** (e.g., on a network) but accessible by the server **60** via, e.g., a wired or wireless interface **992**, **994**. For ease of illustration, it is assumed that the database of FIG. **4**B corresponds to the database **372** of FIG. **3**B.

[0074] For example, the database **372** shows the monitor patch **20**A having one linkable bridge **40**A which is also the selected bridge. The database **372** also shows the monitor patches **20**B and **20**C having the same linkable bridges **40**B, **40**C of which the bridges **40**B is the selected bridge for the both monitor patches. The database **372** also shows the monitor patch **20**D having the same linkable bridges **40**B, **40**C of which the bridge **40**C is the selected bridge. The above portions of the database **372** relating to the monitor patches **20**B-D reflect the fact that the monitor patches **20**B, **20**C are in the room **410**B having the bridge **40**B located therein, while the monitor patch **20**D is in the room **410**C having the bridge **40**C located therein. Therefore, while the bridge **40**B is capable of communicating with the monitor patch **20**D due to their close proximity, the bridge **40**C is selected for the monitor patch **20**D, e.g., by the server **60**, due to the bridge's closer proximity to the monitor patch **20**D. The database **372** also shows the monitor patch **20**M worn by the patient **10**M having three linkable bridges **40**I, **40**J, **40**K of which the bridge **40**J is the currently selected bridge; and the monitor patch **20**P worn by the patient **10**P having two linkable bridges **40**C, **40**N of which the bridge **40**N is the currently selected bridge.

[0075] The signal levels (third column) associated with various bridge-patch communication links in the database **372** represent the strengths of wireless signals (e.g., acknowledgment signals) from the bridges **40**A-O received by the monitor patches **20**A-op. As will be described below with respect to FIG. **9**, the signal levels can be used for a bridge selection by the surveillance server **60**.

[0076] FIG. **5**A is a map of the exemplary healthcare facility **400** depicted in FIG. **4**A after a passage of time from the map of FIG. **4**A. The map of FIG. **4**B is the same as the map of FIG. **4**A except for the following changes:

[0077] 1) The patient **10**A wearing the monitor patch **20**A has left the facility **400**.

[0078] 2) The patient **10**M wearing the monitor patch **20**M has now returned to her patient room **410**G.

[0079] 3) The patient **10**P wearing the monitor patch **20**P and walking along the hallway **420**A has now progressed to the middle of the hallway **420**A.

[0080] In response to the changes, the surveillance server **60** has updated the database **372** discussed above with respect to FIG. **4**B. FIG. **5**B is a portion of an updated version of the database **372** shown in FIG. **4**B according to certain embodiments of the present disclosure. The updated database **372** shows the monitor patch **20**A having neither a linkable bridge nor a selected bridge, reflecting the fact that the monitor patch **20**A is longer in communication range of any of the bridges in the monitoring system. The updated database also shows the monitor patch **20**M now having three linkable bridges **40**H, **40**I, **40**K of which the bridge **401** is the currently selected bridge, reflecting the fact that the monitor patch **20**M is now in the room **4100** having the bridge **401** located therein. The updated database also shows the monitor patch **20**P having two linkable bridges **40**N, **40**O of which the bridge **40**O is the currently selected bridge. In the illustrated example of FIG. **5**A, the monitor patch **20**P is substantially equidistant from both the bridge **40**N and the bridge **40**O and the respective signal strengths are similar (19 versus 17). Hence, the monitor patch **20**P can be served equally well by both bridges **40**N, **40**O. Notwithstanding the fact that the signal strength associated with the bridge **40**N is slightly higher than that associated with the bridge **40**O, control software in the surveillance server **60** has selected the bridge **40**O based on the consideration that the monitor patch **20**P worn by the patient **10**P has been moving towards the bridge **40**O and away from the bridge **40**N and, hence, is likely to be served longer by the former bridge **40**O than by the latter bridge **40**N.

[0081] Henceforth, specific reference numbers (e.g., bridge **40**A, monitor patch **20**C) will be used when referring to specific devices, while generic references (bridge **40**, monitor patch **20**) will be used when referring to devices in a general sense.

[0082] A communication link between a bridge **40** and a monitor patch associated **20** associated with a patient can be considered established, for example, when the bridge **40** has received one or more regularly transmitted signals (e.g., those indicative of vital signs of the patient) from the monitor patch **20** or when the bridge **40** has received an acknowledgment signal from the bridge **40** in response to a query signal sent out via the bridge **40**. From the perspective of the monitor patches **20**, the bridge is one of linkable bridges for the monitor patches **20**. Conversely, an established communication link between a bridge **40** and a monitor patch **20** can be considered lost when the bridge **40** can no longer receive regularly transmitted signals from the monitor patch **20** or when the bridge **40** does not receive an acknowledgment signal from the monitor patch **20** in response to a query signal.

[0083] In certain embodiments, upon occurrence of a new communication link or loss of an existing communication link, the bridge **40** automatically sends the message to the surveillance server **60** (FIG. **1**), which, in turn, updates the database **372** stored in memory (e.g., **370**) associated with the server **60**, such as a hard disk or an external data storage device accessible by the server. In some embodiments, each of the bridges **40**A-O includes memory (e.g., **312**, **340** of FIG. 3A) for storing a list or database **342** of monitor patches **20**A-O with which the bridge **40** has established communication links. A processor (e.g., **310** of FIG. 3A) executing control software in the bridge **40** can update the list **342** stored in the memory (e.g., **312**, **340**) of the bridge **40** to keep the list current. The processor **310** then sends the updated list **342** or a portion thereof to the surveillance server **60**.

[0084] FIG. **6**A shows a first list **610**A stored in the bridge **40**A at the time of FIG. **4**A, and a second list **620**A which corresponds to an updated list stored in the bridge **40**A at the time of FIG. **5**A. The first column of the first list **610**A enumerates linkable patches corresponding to all monitor patches with which the bridge **40**A has established communication links at the time of FIG. **4**A. The second column of the first list **610**A enumerates associated patches corresponding to all monitor patches **20** for which the bridge **40**A has been selected for communicative association at the time of FIG. **4**A. As can be seen from FIG. **4**A and correspondingly reflected in the first list **610**A, the bridge **40**A has an established communication link only with the monitor patch **20**A. The bridge **40**A is also the selected bridge **40** for the monitor patch **20**A, or, conversely, the monitor patch **20**A is an associated patch for the bridge **40**A. As can be seen from FIG. **5**A and correspondingly reflected in the second list **620**A, the bridge **40**A has neither a linkable patch nor an associated patch at the time of FIG. **5**A, reflecting the fact that between the time of FIG. **4**A and the time of FIG. **5**A, the patient **10**A wearing the monitor patch **20**A has left the healthcare facility **400**, or the patch **20**A has been removed and deactivated.

[0085] FIG. **6**B shows a first list **610**B stored in the bridge **401** at the time of FIG. **4**A, and a second list **620**B that corresponds to an updated list stored in the bridge **401** at the time of FIG. **5**A. As can be seen from FIG. **4**A and correspondingly reflected in the first list **610**B, the bridge **40**A has established communication links with the monitor patches **20**K and **20**L of which the monitor patch **20**L is the associated patch. As can be seen from FIG. **5**A and correspondingly reflected in the second list **620**B, the bridge **401** has established communication links with the monitor patches **20**K, **20**L, and **20**M of which the monitor patches **20**L and **20**M are the associated patches at the time of FIG. **5**A, reflecting the fact that between the time of FIG. **4**A and the time of FIG. **5**A, the patient **10**M wearing the monitor patch **20**M has entered the patient room **410**G.

[0086] FIG. **6**C shows a first list **610**C stored in the bridge **40**N at the time of FIG. **4**A, and a second list **620**C which corresponds to an updated list stored in the bridge **40**N at the time of FIG. **5**A. As can be seen from FIG. **4**A and correspondingly reflected in the first list **610**B, the bridge **40**N has established communication links with the monitor patches **20**F and **20**P of which the monitor patch **20**P is the associated patch. As can be seen from FIG. **5**A and correspondingly reflected in the second list **620**B, the bridge **40**N has established communication links with the monitor patches **20**, but has no associated patch, reflecting the condition that between the time of FIG. **4**A and the time of FIG. **5**A, the patient **10**P wearing the monitor patch **20**P has progressed to the center of the hallway **420**A towards the bridge **400** and the surveillance server **60** has selected the bridge **40**O for the monitor patch **20**P as discussed above with respect to FIG. **5**B.

[0087] FIG. **7** is a flowchart illustrating a process **700** for tracking locations of monitor patches **20** by keeping and updating a database comprising information indicative of the monitor patches **20** and their linkable and selected bridges **40** according to certain aspects of the present disclosure. For the purposes of illustration only, without any intent to limit the scope of the present disclosure in any way, the process **700** will be described with reference to FIGS. **1**, **4**A-B, and **5**A-B. The process **700** begins at start state **701** and proceeds to operation **710** in which a surveillance server **60** receives a message from a bridge **40** indicating that the bridge **40** has established a new communication link with a monitor patch **20** or lost an existing communication link with a monitor patch **20** or both. For example, if the message were sent from the bridge **40**A of FIGS. **4**A and **5**A, the message would indicate loss of an existing communication link with the monitor patch **20**A. On the other hand, if the message were sent from the bridge **401**, the message would indicate a new (previously unavailable) communication link with the monitor patch **20**M.

[0088] FIG. **8**A is a diagram illustrating an exemplary data structure for a message **800**A indicating a new communication link and/or loss of an existing communication link according to certain aspects of the present disclosure. In the illustrated example, the message **800**A includes a header field **810**A for storing a message header, an ID field **820**A for storing an ID for a bridge sending the message, a data field **830**A for storing information relating to a new communication link and/or loss of an existing communication link, and optionally a field **840** for storing a checksum. The header field **810**A can include subfields for indicating a total number of monitor patches with which the bridge has established new communication links and a total number of monitor patches with which the bridge has lost existing communication links. The data field **830**A includes a first subfield **832**A for storing an ID for a monitor patch that the bridge has established a new communication link, a second subfield **833**A for storing data indicative of a signal level or strength associated with the new communication link, and a third subfield **836**A for storing an ID for a monitor patch with which the bridge has lost an existing communication link. If the message **800**A were sent from the bridge **40**A while transitioning from the configuration of FIG. **4**A to the configuration of FIG. **5**A, the ID field **820** would include data indicative of the bridge **40**A, and the third subfield **836**A would include data indicative of the monitor patch **20**A. The message embodiment shown in FIG. **8**A is exemplary only, as other message embodiments may be employed. The surveillance server **60** upon receiving the message **830**A can update the database such as the one shown in FIG. **4**B as further described below.

[0089] FIG. **8**B is a diagram illustrating an exemplary data structure for an alternative message **800**B indicating a new communication link and/or loss of an existing communication link according to alternative aspects of the present disclosure. In the illustrated example, the message **820**B includes a header field **810**B for storing a message header, an ID field **820**B for storing an ID for a bridge sending the message, a data field **830**B for storing information relating to all monitor patches with which the bridge has established communication links, and a field **840**B for storing a checksum. The header field **810**A can include subfields for indicating a total number of linkable monitor patches **20** with which the bridge **40** has established communication links. The data field **830**B includes a first subfield **832**B for storing an ID of a first likable monitor patch **20**, a second subfield **833**B for storing data indicative of a signal strength or level associated with the communication link between the bridge **40** and the first likable monitor patch **20**. The data field **830**B includes other subfields **834**B, **835**B, **836**B, **837**B for storing ID's and data indicative signal strengths for additional likable monitor patches **20**. If the message were sent from the bridge **401** in the configuration of FIG. **5**A (corresponding to the list **620**B of FIG. **6**B), the data fields **832**B, **834**B, **836**B would include data indicative of the monitor patches **20**K, **20**L, **20**M, respectively, for example. In certain embodiments, each of the subfields **832**B, **834**B, **836**B includes a single bit for indicating whether the monitor patch **20** indicated by the subfield is associated with the bridge **40** or not (i.e., whether the bridge **40** is the selected bridge **40** for the monitor patch **20**). In those embodiments, such a bit would be clear for the subfield **832**B (for the monitor patch **20**K), but set for the subfields **834**B, **836**B (for the monitor patches **20**L, **20**M). The message embodiment of FIG. **8**A is exemplary only, as other message embodiments may be employed. The surveillance server **60**, upon receiving the message **830**B, can update the database such as the one shown in FIG. **4**B as further described below.

[0090] Returning to FIG. **7**, the process **700** proceeds to decision state **720** in which it is determined whether the received message indicates that the bridge **40** sending the message has established at least one new communication link with a monitor patch **20**, e.g., by starting to receive regularly transmitted signals from the monitor patch. In case of the message **800**A of FIG. **8**A, this determination can involve control software running in a processor of the surveillance server **60** searching for nonzero data in the data field **832**A ("NEW PATCH ID"). In case of the message **800**B of FIG. **8**B, this determination can involve the control software comparing the linkable monitor patches **20** indicated in the data field **830**B of the message **800**B to previously stored linkable monitor patches **20** for the bridge **40** in order to discover one or more monitor patches **20** that are newly present in the message. If it is determined at the state **720** that no new communication link has been established for the bridge **40** (NO), the process **700** proceeds to decision state **730** to be described below.

[0091] On the other hand, if it is determined at the decision state **720** that at least one new communication link has been established for the bridge **40** (YES), the process **700** proceeds to operation **725** in which database **372** comprising information indicative of communication links between monitor patches **20**A-O and bridges **40**A-O is accessed and the new communication link is added to the database. Examples of such additions include the communication links between the monitor patch **20**M and the bridge **401** and the communication link between the monitor patch **20**P and the bridge **40**O, both of which are not present in the database shown in FIG. **4**A but present in the updated database shown in FIG. **5**B. The process **700** then proceeds to decision state **730** described below.

[0092] In the decision state **730** it is determined whether the received message indicates that the bridge **40** sending the message has lost at least one existing communication link with a monitor patch **20**, e.g., by failing to receive regularly transmitted signals from the monitor patch **20**. In case of the message **800**A of FIG. **8**A, this determination can involve control software running in a processor of the surveillance server **60** looking for nonzero data in the subfield **836**A. In case of the message **800**B of FIG. **8**B, this determination can involve the control software comparing the linkable monitor patches **20** indicated in the data field **830**B of the message **800**B to previously stored linkable monitor patches **20** for the bridge **40** in order to discover one or more monitor patches **20** that are not longer present in the message.

[0093] If it is determined at the decision state **730** that no existing communication link has been lost for the bridge **40** (NO), the process **700** ends at state **703**. On the other hand, if it is determined at the decision state **730** that at least one existing communication link has been lost for the bridge (YES), the process **700** proceeds to operation **725** in which a database comprising information indicative of communication links between monitor patches **20**A-O and bridges **40**A-O is accessed and the communication link is deleted from the database. Examples of such deletion include the communication link between the monitor patch **20**M and the bridge **403** and the communication link between the monitor patch **20**P and the bridge **40**C, which is present in the database shown in FIG. **5**A but not present in the updated database shown in FIG. **5**B. The process **700** ends at state **703**.

[0094] Therefore, the surveillance server **60**, by maintaining and updating a database of bridge-patch communication links using a process such as the process **700** based on messages received from bridges **40**, can track locations of monitor patches **20**A-O in the healthcare facility **400**. In certain embodiments, the surveillance server **60**, after receiving one or more of such messages or at scheduled intervals, can select a particular bridge **40** among a set of linkable bridges **40** for a particular monitor patch **20**. After such a bridge selection, in certain embodiments, the server **60** prevents other linkable but unselected bridges **40** from communicating with the particular monitor patch **20**.

[0095] FIG. **9** is a flowchart illustrating an exemplary process **900** for a bridge selection process according to certain aspects of the present disclosure. The process **900** begins at start state **901** and proceeds to decision state **910** in which it is determined whether there are multiple bridge-patch communication links (e.g., multiple linkable bridges) available for a particular monitor patch **20**. If it is determined at the decision state **910** that there is only one communication link (e.g., one linkable bridge) available for the monitor patch, the process **900** proceeds to another decision state **930** to be described below. On the other hand, if it is determined at the decision state **910** that there are multiple communication links (e.g., multiple linkable bridges **40**) for the monitor patch **20**, the process **900** proceeds to operation **920** in which signal strengths of the multiple communication links are compared, and a bridge **40** associated with the highest signal strength is identified. For example, in case of the monitor patch **20**M in the configuration of FIG. **4**B, the communication link between the monitor patch **20**M and the bridge **40**J has the highest signal strength (19) among all available communication links.

[0096] The process **900** proceeds to decision state **930** in which it is determined whether the bridge **40** being considered for selection (e.g., the only bridge in case of one communication link or the identified bridge in case of multiple communication links) is available for communication with the monitor patch **20**. This determination can involve determining by the surveillance server **60** or by the bridge **40** the number of monitor patches **20** with which the bridge **40** is currently associated (e.g., the number of monitor patches to which the bridge is currently the selected bridge) in order to determine whether the bridge **40** is currently overloaded. If it is determined at the decision state **930** that the bridge **40** being considered for selection is not available (NO), the process **900** proceeds to decision state **940** in which it is determined whether there are one or more other linkable bridges **40** with which the monitor patch **20** can be associated. If it is determined at the decision state **940** that there is no other linkable bridge **40** (NO), the process **900** ends at state **903**. On the other hand, if it is determined at the decision state **940** that there are one or more other linkable bridges **40** (YES), the process **900** proceeds to operation **945** in which another linkable bridge **40** associated with the next highest signal strength is identified, and then back to the decision state **930** for determining availability of the other bridge **40**.

[0097] On the other hand, if it is determined at the decision state **930** that the bridge **40** being considered for selection is available (YES), the process **900** proceeds to decision state **950** in which it is determined whether the selection of the bridge **40** being considered is consistent with other considerations. For example, as indicated above with respect to FIG. **5**B, control software running in the surveillance server **60** selected the bridge **40**O over the bridge **40**N in spite of the condition that the signal strength associated with the bridge **40**N is currently stronger than the signal strength associated with the bridge **40**O. The selection is based on the additional consideration that the patch **20**P has been moving away from the bridge **40**N and towards the bridge **40**O.

[0098] If it is determined at the decision state **930** that the selection of the bridge **40** is not consistent with other considerations (NO), the process **900** proceeds to the decision state **940** and to the operation **945** and back to the decision state **930** as discussed above. On the other hand, if it is determined at the decision state **930** that the selection of the bridge **40** is consistent with other considerations (YES), the process **900** proceeds to operation **960** in which the bridge **40** is selected for the monitor patch **20** and, the database of bridge-patch communication links is updated to reflect the new selection. The process **900** ends at state **903**.

[0099] At times, a bridge **40** can lose power or break down or otherwise become inoperable and can no longer carry data between associated monitor patches **20** and the surveillance server **60**. For example, if the bridge **401** becomes inoperable, the monitor patches **201**, and **20**M can no longer send data to the surveillance server **60** via the bridge **401**. In certain embodiments, the surveillance server **60**, upon recognition of such an occurrence, selects alternative bridges **40** for the monitor patches **20** so as to route data between the monitor patches **20** and the surveillance server **60** via the alternative bridges **40**.

[0100] FIG. **10** is a flowchart illustrating a process **1000** for detecting an inoperable bridge **40** and selecting an alternative bridge **40** to replace the inoperable bridge **40** for the monitor patches **20** that were previously associated with the inoperable bridge **40** according to certain aspects of the present disclosure. The process **1000** begins at start state **1001** and proceeds to decision state **1010** in which it is determined whether an inoperable selected bridge **40** has been detected. The determination can include failing to receive regularly transmitted messages from the selected bridge **40** or failing to receive an acknowledgment message from the bridge **40** in response to a query message sent to the bridge **40** by the surveillance server **60**. If it is determined at the decision state **1010** that an inoperable selected bridge **40** has not been detected (NO), the process **1000** loops back to the decision state **1010** to await such an occurrence. On the other hand, if an inoperable selected bridge **40** has been detected (YES), the process **1000** proceeds to operation **1020** in which a monitor patch **20** associated with the selected bridge **40** is identified from, e.g., database (e.g., **372**) such as the ones shown in FIGS. **4**B and **5**B. For example, if the selected bridge found to be inoperable is the bridge **40**D, the monitor patch **20**E can be identified. After the identification, the process proceeds to decision state **1030**.

[0101] In the decision state **1030**, it is determined whether there are one or more alternative linkable bridges **40** for the identified monitor patch from, e.g., a list in a database such as the ones shown in FIGS. **4**B and **5**B. If it is determined at the decision state **1030** that there is no alternative bridge **40** (NO), the process **1000** proceeds to decision state **1050** which will be described below. On the other hand, if it is determined at the decision state **1030** that there are one or more alternative linkable bridges **40** for the identified monitor patch (YES) (the bridge **40**B for the monitor patch **20**E in the above example), the process **1000** proceeds to operation **1040** in which a bridge selection process such as the one described above with respect to FIG. **9** is performed in order to select an alternative bridge **40** for the identified monitor patch **20**,

[0102] The process **1000** then proceeds to decision state **1050** in which it is determined whether there is another monitor patch **20** associated with the selected bridge **40** determined to be inoperable at the decision state **1010**. If it is determined at the decision state **1050** that there is no other monitor patch **20** associated with the inoperable bridge **40**, the operation **1000** ends at state **1003**. On the other hand, if it is determined at the decision state **1050** that there is another monitor patch **20** associated with the inoperable bridge **40** (YES) (the monitor patch **20**E for the bridge **40**D in the above example), the process **1000** loops back to the decision state **1030** in which it is determined where there are one or more alternative bridges **40** for the other monitor patch **20** and then to the selection operation **1040** and decision state **1050**. The loop is repeated until it is determined at the decision state **1050** that there is no other monitor patch **20** associated with the inoperable bridge **40** in which case the process **1000** ends at state **1003**.

[0103] In certain aspects, the knowledge of locations of monitor patches (e.g., **20**A-O of FIGS. **4**A and **4**B) can be used for tracking patients (e.g., **10**A-O) wearing the monitor patches **20** in a healthcare facility (e.g., hospital). As discussed above with respect to FIG. **7**, a surveillance server (e.g., **60** of FIG. **1**) can track locations of monitor patches **20** by keeping and updating database **372** comprising information indicative of the monitor patches **20** and their linkable and selected bridges **40** based on messages received from various bridges **40**. Therefore, assuming that the locations of various bridges **40** in the facility and the names of patients **10** to whom the monitor patches **20** are assigned are known, locations of the patients **10** can also be tracked.

[0104] FIG. **11** is a flowchart illustrating a process **1100** for determining locations of patients **10** in a healthcare facility according to certain aspects of the present disclosure. The process **1100** begins at start state **1101** and proceeds to operation **1110** in which a surveillance server **60** receives a signal comprising information relating to a monitor patch **20** attached to a patient **10** from a selected bridge **40** for the monitor patch **20**. The signal can be, for example, one of the messages **800**A and **800**B discussed above with respect to FIGS. **8**A and **8**B. After receiving the signal, surveillance server **60** can update database **372** such as the ones shown in FIGS. **4**A and **4**B as discussed above with respect to FIG. **7**. In certain embodiments, the signal is generated by the bridge **40** in response to a newly established communication link between the bridge **40** and the monitor patch **20** trigged by the patient **10** being moved into her new patient room. In other embodiments, the signal is generated by the bridge **40** in response to a query signal sent to the bridge **40** by the surveillance server **60**.

[0105] The process **1100** proceeds to operation **1120** in which a patient to whom the monitor patch **20** is attached is identified. In certain embodiments, the identification operation includes control software running in the surveillance server **60** accessing a database such as the one shown in FIG. **12**A that lists monitor patches **20** (first column) and their assigned patients **10** (second column). In other embodiments, the received signal includes information indicative of the patient **10** (e.g., the patient ID), and the control software extracts the information from the signal. The process **1100** proceeds to operation **1130** in which location of the patient **10** is determined. In certain embodiments, the operation **1130** includes the control software accessing a database such as the one shown in FIG. **12**B that lists locations of various bridges **40** in the facility. In other embodiments, the received signal includes information indicative of the location of the bridge **40** that sent the signal, and the control software extracts the information from the signal. In some embodiments, the determined location (e.g., "Room **3**") is displayed on a display associated with a hospital system (e.g., the workstation **100** of FIG. **1**). Alternatively, the display can graphically indicate the patient location on a hospital map such as the ones shown FIGS. **4**A and **4**B.

[0106] The foregoing description is provided to enable any person skilled in the art to practice the various embodiments described herein. While the foregoing embodiments have been particularly described with reference to the various figures and embodiments, it should be understood that these are for illustration purposes only and should not be taken as limiting the scope of the claims.

[0107] The word "exemplary" is used herein to mean "serving as an example or illustration." Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0108] A reference to an element in the singular is not intended to mean "one and only one" unless specifically stated, but rather "one or more." The term "some" refers to one or more. Underlined and/or italicized headings and subheadings are used for convenience only, do not limit the invention, and are not referred to in connection with the interpretation of the description of the invention. All structural and functional equivalents to the elements of the various embodiments of the invention described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and intended to be encompassed by the invention. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the above description.

What is claimed is:

1. A method for tracking a patient within a facility via a vital-signs patch attached to the patient, the method comprising:

receiving a first signal from a bridge, the first signal comprising information indicative of a vital-signs patch attached to a patient;

identifying the patient based at least in part on the information; and

determining location of the patient based on a known location of the bridge within the facility.

2. The method of claim **1**, wherein the first signal from the bridge is received by a surveillance server, the surveillance server configured to collect data relating to one or more vital-signs of the patient.

3. The method of claim **1**, wherein the identifying comprises accessing a database comprising information indicative of associations between vital-sign monitor patches and patients.

4. The method of claim **1**, wherein the identifying comprises extracting information indicative of the patient from the first signal.

5. The method of claim **1**, wherein the determining comprises accessing a database comprising information indicative of locations of a plurality of bridges within the facility.

6. The method of claim **1**, wherein the first signal is generated by the bridge in response to a second signal received by the bridge, the second signal comprising information indicative of the vital-sign monitor patch.

7. A vital-sign monitoring system, comprising:

a plurality of vital-sign monitor patches configured to monitor one or more vital-signs of patients to whom the vital-sign monitor patches are attached;

a surveillance server configured to collect data relating to the one or more vital-signs of the patients from the plurality of vital-sign monitor patches; and

a plurality of bridges at respective locations within a facility and configured to provide data connections between the plurality of vital-sign monitor patches and the surveillance server;

wherein the surveillance server is configured to:

receive a first signal from a bridge in the monitoring network, the first signal comprising information indicative of a vital-sign monitor patch attached to a patient,

identify a patient based at least in part on the first signal, and

determine location of the patient based on a known location of the bridge within the facility.

8. The system of claim **7**, wherein the one or more vital-signs include at least one of body temperature, pulse rate, blood pressure, and respiratory rate.

9. The system of claim **7**, wherein the surveillance server is configured to identify the patient by accessing a database comprising information indicative of associations between vital-sign monitor patches and patients.

10. The system of claim **9**, wherein the surveillance server is configured to determine the location of the patient by accessing a database comprising information indicative of locations of the plurality of bridges within the facility.

11. The system of claim **9**, wherein the database is associated with the surveillance server.

12. The system of claim **7**, wherein the surveillance server is configured to identify the patient by extracting information indicative of the patient from the first signal.

13. The system of claim **7**, wherein the surveillance server is configured to send a second signal comprising a request for a search of at least one of the vital-sign monitor patch and the patient to the plurality of bridges, the first signal generated by the bridge in response to the second signal.

14. The system of claim **7**, wherein the vital-sign monitor patch has a plurality of communication links with two or more bridges among the plurality of bridges.

15. The system of claim **14**, wherein the surveillance server is configured to receive a plurality of signals from the two or more bridges, the plurality of signals comprising information indicative of signal strengths of respective communication links.

16. The system of claim **15**, wherein the surveillance server is configured to use location of a bridge reporting a highest signal strength as the location of the patient.

17. The system of claim **7**, wherein at least one bridge among the plurality of bridges includes a memory for storing a list of vital-sign monitor patches with which the at least one bridge has established communication links.

18. The system of claim **17**, wherein the list further includes information indicative of patients to whom the vital-sign monitor patches are attached.

19. The system of claim **17**, wherein the at least one bridge is configured to update the list when the at least one bridge has established a new communication link with a vital-sign monitor patch.

20. The system of claim **17**, wherein the at least one bridge is configured to update the list when the at least one bridge has lost an existing communication link with a vital-sign monitor patch.

21. The system of claim **17**, wherein the at least one bridge is configured to send the first signal to the surveillance server when the at least one bridge has established a new communication link with a vital-sign monitor patch.

* * * * *

专利名称(译)	用于在生命体征监测系统中对患者进行位置跟踪的系统和方法		
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申请(专利权)人(译)	CAREFUSION 303，INC.		
当前申请(专利权)人(译)	CAREFUSION 303，INC.		
[标]发明人	BEAUDRY SERGE JAFRI AMIR		
发明人	BEAUDRY, SERGE JAFRI, AMIR		
IPC分类号	A61B5/00 G06F7/04		
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摘要(译)

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