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**Alsafadi et al.**

(54) **WIRELESS MEDICAL MONITORING DEVICE**

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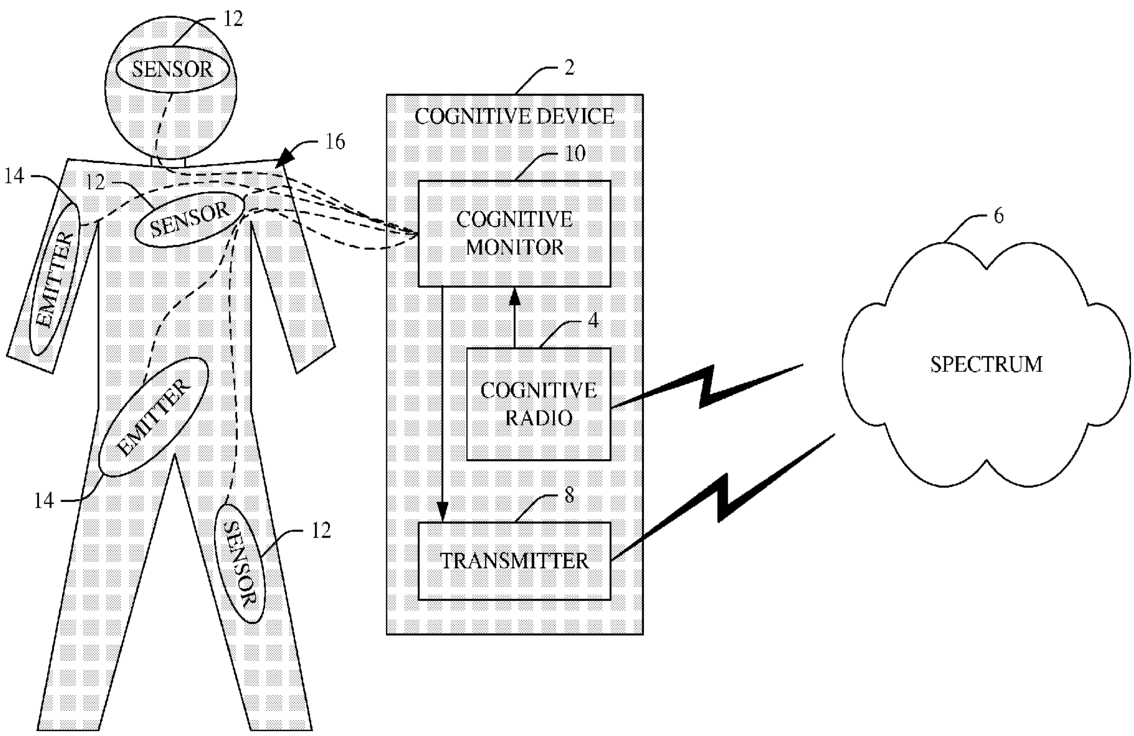
(57) **ABSTRACT**

Described herein is a patient monitoring system that includes a body network (**16**) with at least one sensor (**12**) that senses physiological information about a patient and a cognitive device (**2**) for communicating the physiological information to a remote location. The cognitive device includes a cognitive radio (**4**), a cognitive monitor (**10**), and a transmitter (**8**). The cognitive radio (**4**) checks detected frequency spectra (**6**) for unused bandwidth and recommends one or more bands on which to transmit clinically relevant information received from the body network (**16**) to the remote location; the cognitive monitor (**10**) receives the information from the body network (**16**), prioritizes the information based at least in part on a set of rules (**30**), and selects which information to transmit based on the prioritization and the recommended transmission bands; and the transmitter (**8**) transmits the selected information as a junction of priority over at least one or the recommended transmission bands.



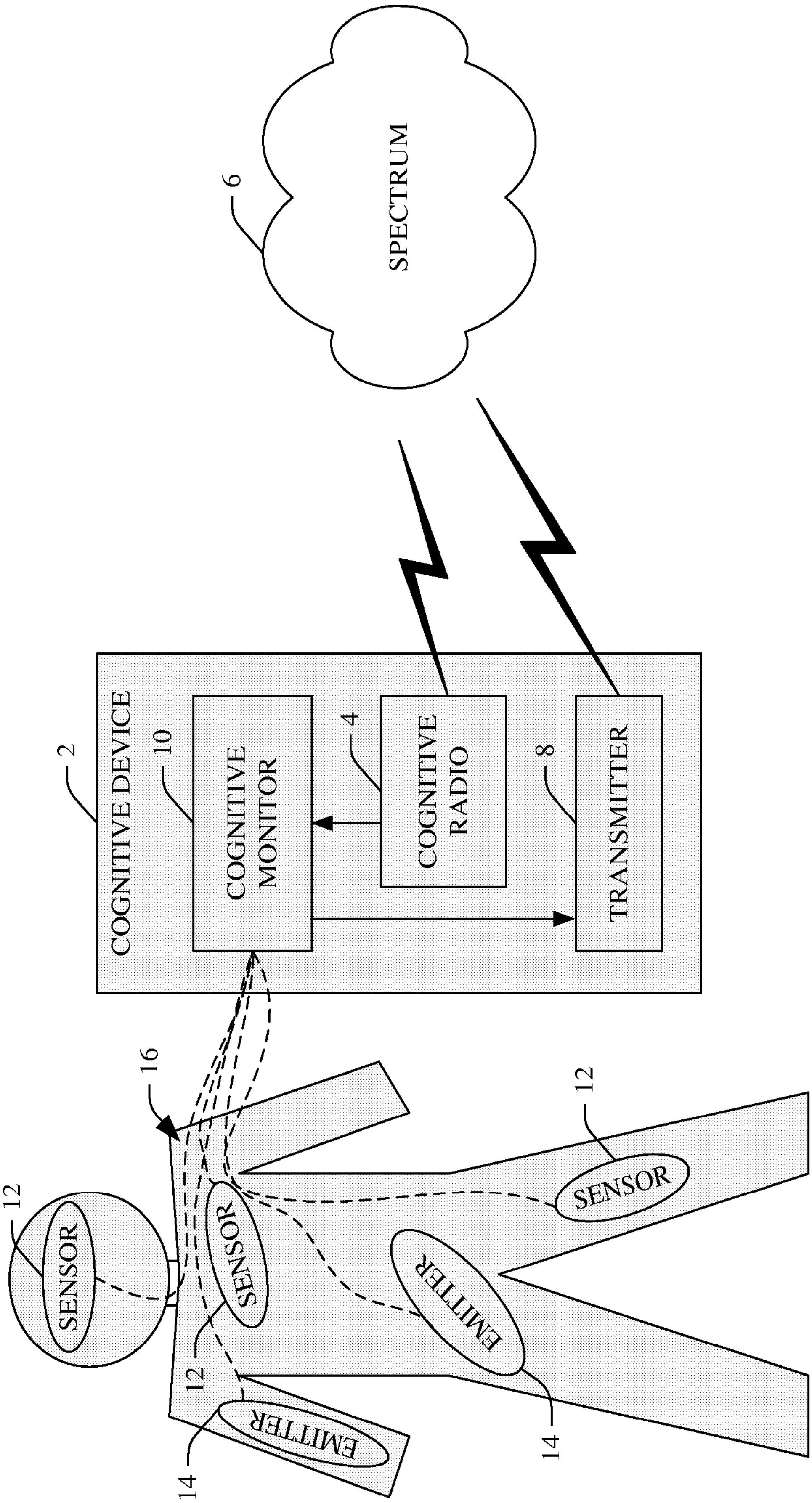

SPECTRUM
6
COGNITIVE DEVICE
2
COGNITIVE MONITOR
10
COGNITIVE RADIO
4
TRANSMITTER
8
SENSOR
SENSOR
SENSOR
12
12
12
EMITTER
EMITTER
14
14
16

FIGURE 1

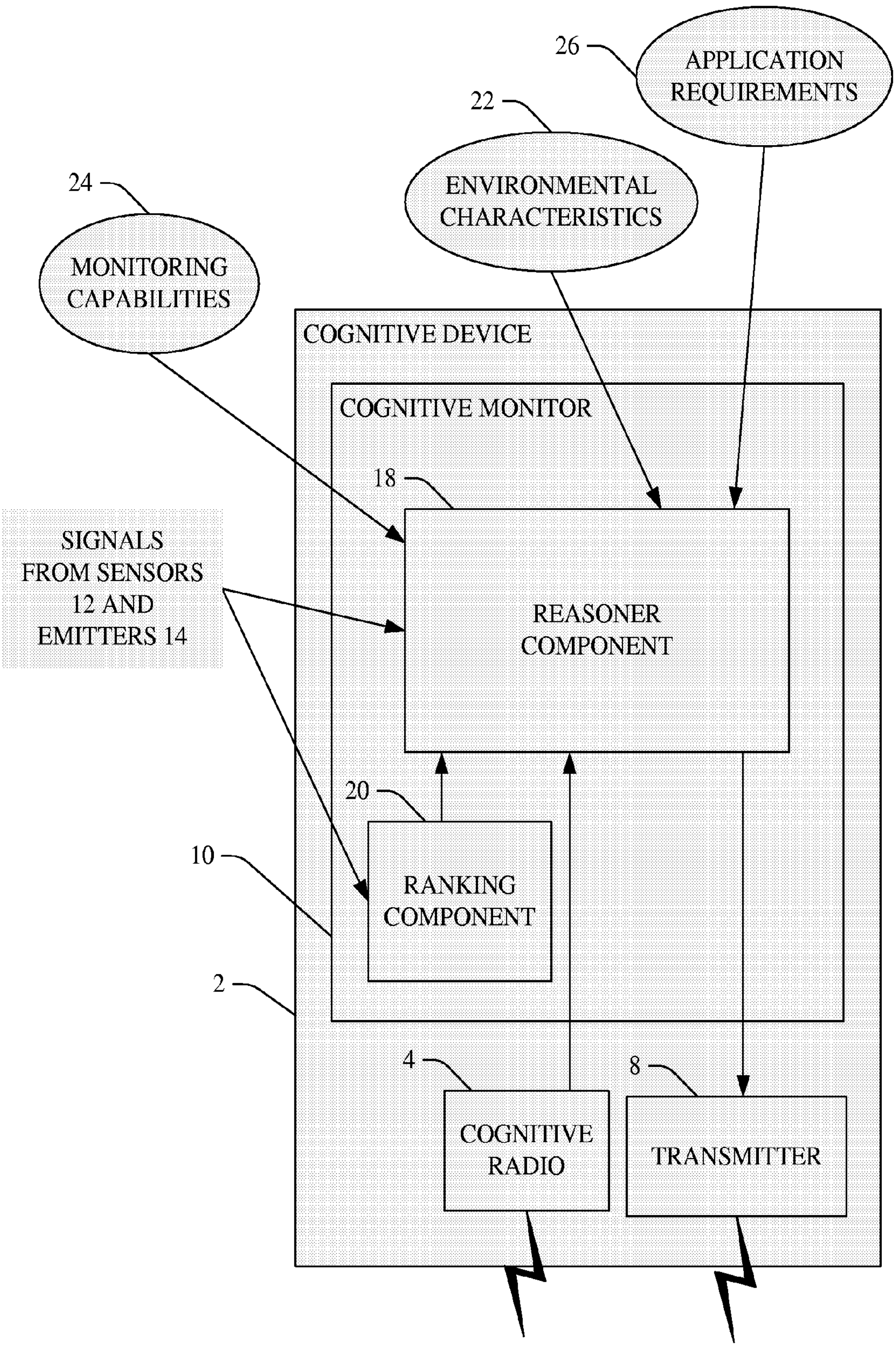
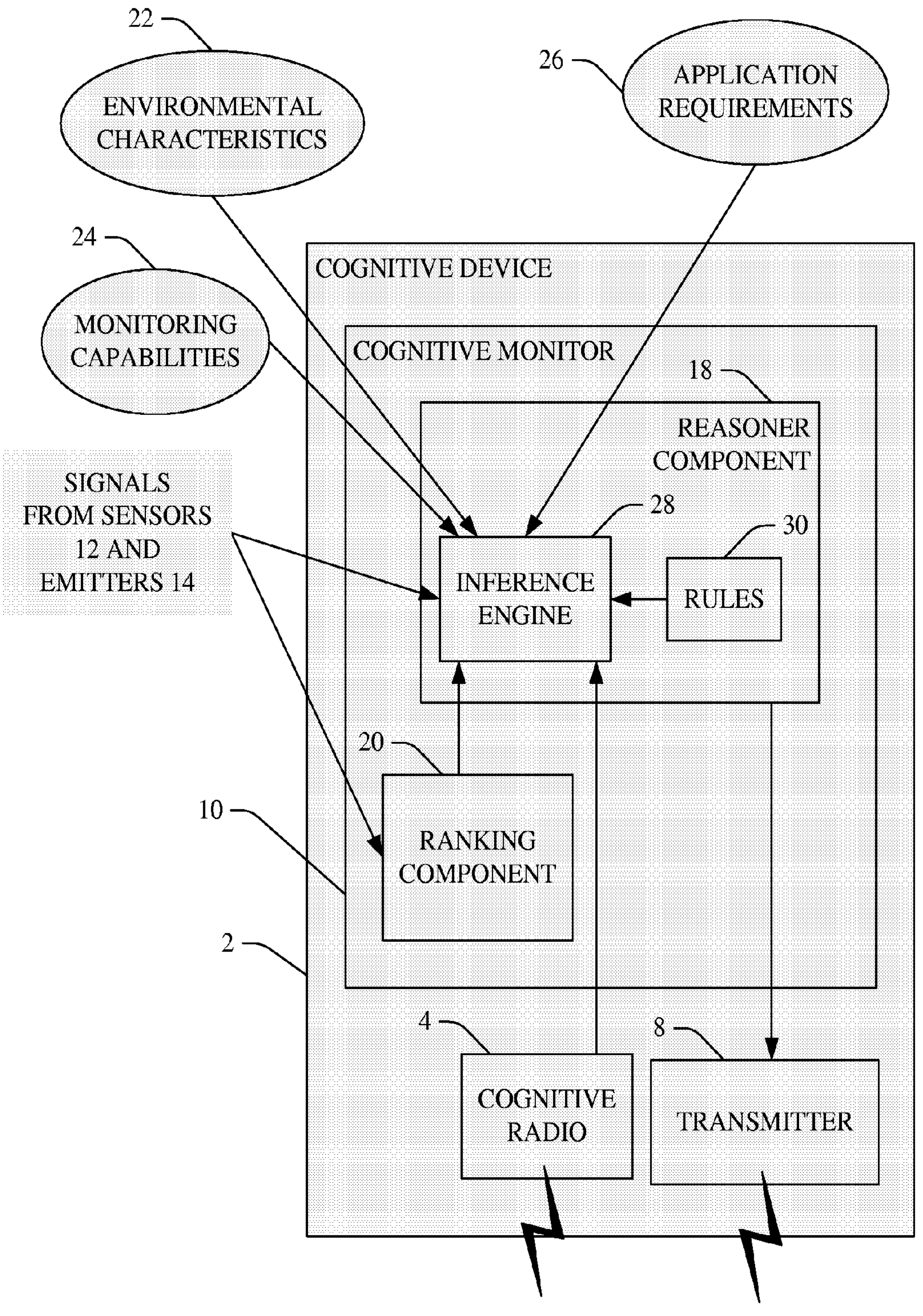

26
APPLICATION REQUIREMENTS
22
ENVIRONMENTAL CHARACTERISTICS
24
MONITORING CAPABILITIES
COGNITIVE DEVICE
COGNITIVE MONITOR
18
SIGNALS FROM SENSORS 12 AND EMITTERS 14
REASONER COMPONENT
20
RANKING COMPONENT
10
2
4
COGNITIVE RADIO
8
TRANSMITTER

FIGURE 2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24
MONITORING CAPABILITIES
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COGNITIVE MONITOR
18
REASONER COMPONENT
SIGNALS FROM SENSORS 12 AND EMITTERS 14
28
30
INFERENCE ENGINE
RULES
20
10
RANKING COMPONENT
2
4
8
COGNITIVE RADIO
TRANSMITTER

FIGURE 3

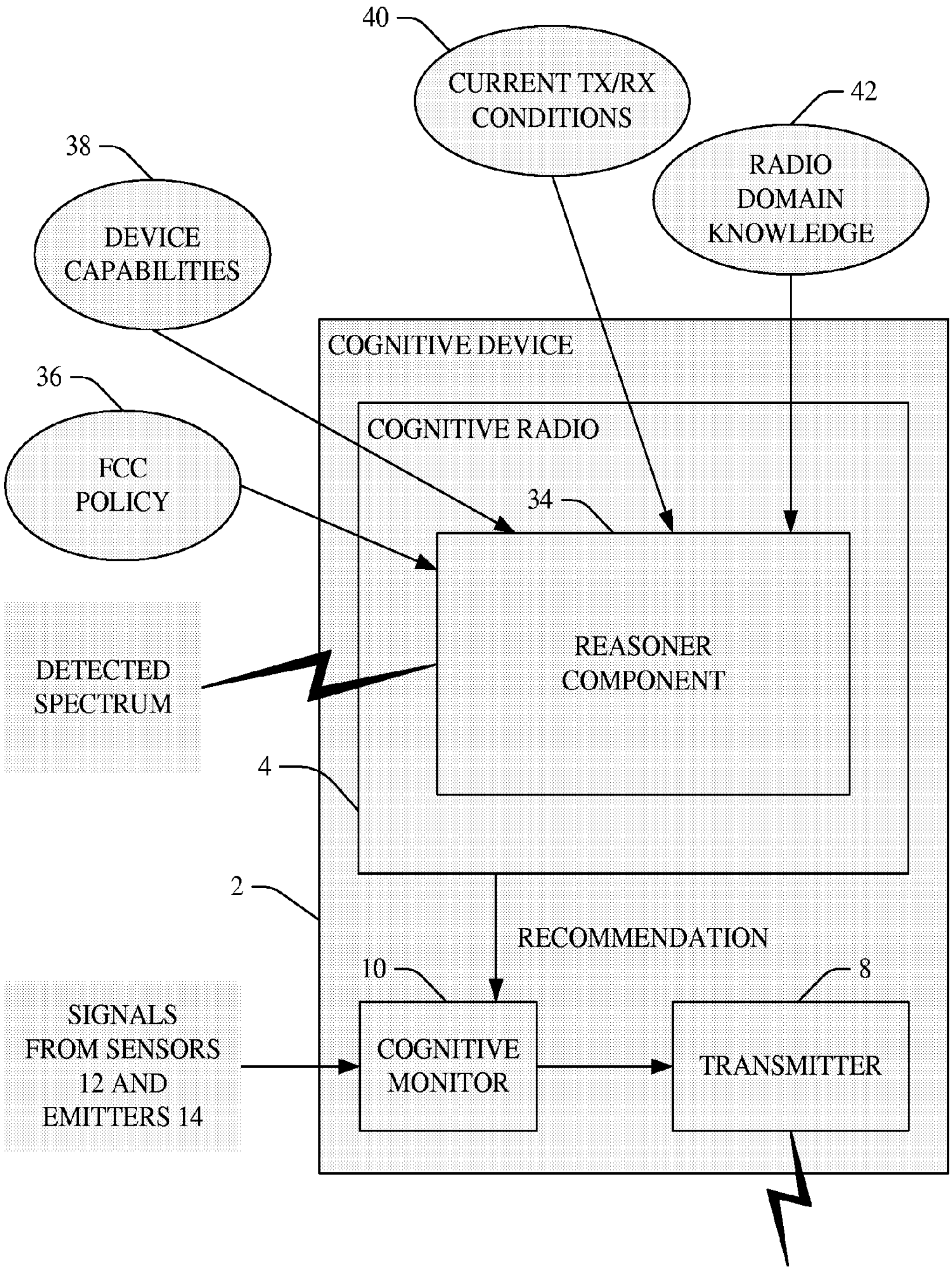
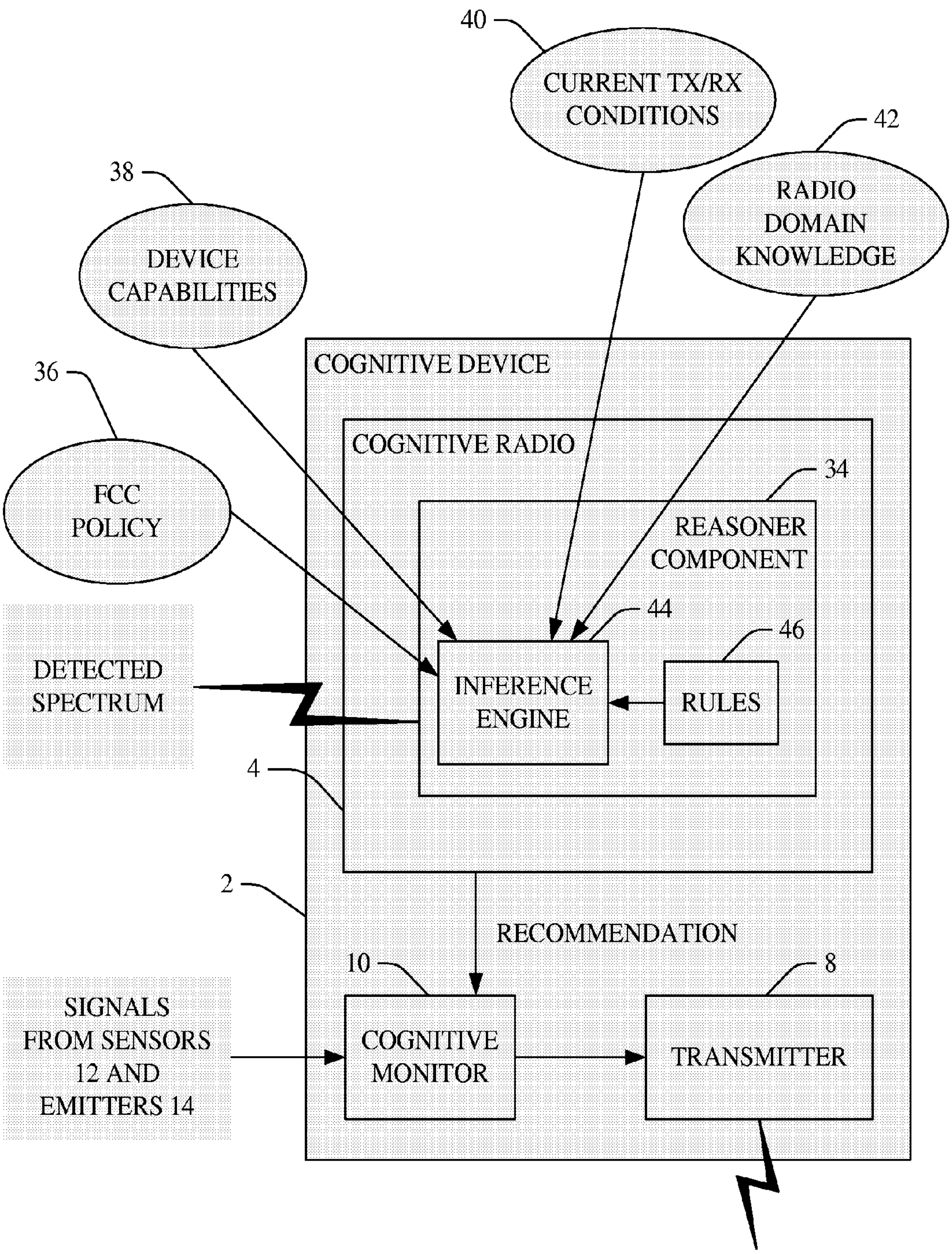

40
CURRENT TX/RX CONDITIONS
42
RADIO DOMAIN KNOWLEDGE
38
DEVICE CAPABILITIES
COGNITIVE DEVICE
36
COGNITIVE RADIO
FCC POLICY
34
DETECTED SPECTRUM
REASONER COMPONENT
4
2
RECOMMENDATION
10
8
SIGNALS FROM SENSORS 12 AND EMITTERS 14
COGNITIVE MONITOR
TRANSMITTER

FIGURE 4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44
46
INFERENCE ENGINE
RULES
DETECTED SPECTRUM
4
2
RECOMMENDATION
10
8
SIGNALS FROM SENSORS 12 AND EMITTERS 14
COGNITIVE MONITOR
TRANSMITTER

FIGURE 5

# WIRELESS MEDICAL MONITORING DEVICE

## DESCRIPTION

**[0001]** The following relates to monitoring a person's physiological state. It finds particular application to wireless body networks and, more particularly, to conveying at least a subset of physiological data signals via previously allocated spectra to a monitoring system. Some aspects are also applicable for general wellness monitoring.

**[0002]** Patients have traditionally been monitored using sensing units connected by wires to a base unit. These wires inhibited patient mobility and were labor intensive to install. To facilitate installation and eliminate wire clutter, wireless sensing units have been developed. Wireless units also enable the patient to move around the room and possibly the ward or the hospital. Outpatients were similarly limited to a convalescent room or possibly their home. Many outpatients, while needing monitoring are well enough to move about the community, but to do so they had to move about unmonitored. Although higher powered wireless monitors are theoretically possible, there are radio frequency communication spectrum problems. Particularly, there is a shortage of frequency bands, and existing bands are crowded.

**[0003]** Spectrum access, use, efficiency, and reliability are critical public policy issues. In response to the increasing demand for spectrum use within a domain of a finite number of frequency bands, the United States Federal Communications Commission (FCC) is looking at proposed rule changes that will allow third parties to use a portion of a previously allocated spectrum when that portion is not being utilized by the controlling party. Currently, they have divided the communications frequency spectrum into many bands that have been allocated, leased or sold to specific users/industries (e.g., radio, television, wire, satellite and cable). The quantity and quality of unused previously allocated spectrum available to third parties and the duration that such spectrum will be available (e.g., remain unused) will vary from allocated party to allocated party.

**[0004]** The following relates to a patient monitoring system that includes a body network with at least one sensor that senses physiological information about a patient and a cognitive device for communicating the physiological information to a remote location. The cognitive device includes a cognitive radio, a cognitive monitor, and a transmitter. The cognitive radio checks detected frequency spectra for unused bandwidth and recommends one or more bands on which to transmit clinically relevant information received from the body network to the remote location; the cognitive monitor receives the information from the body network, prioritizes the information based at least in part on a set of rules, and selects which information to transmit based on the prioritization and the recommended transmission bands; and the transmitter transmits the selected information as a function of priority over at least one or the recommended transmission bands.

**[0005]** One advantage includes wirelessly communicating signals from a wireless Body Area Network (BAN) over previously allocated but unused spectrum for monitoring by a clinician.

**[0006]** Another advantage resides in enabling extended patient monitoring outside the hospital with minimal modification to their lifestyle.

**[0007]** Another advantage is wireless monitoring that can be deployed anywhere in the world with minimal configuration.

**[0008]** Another advantage resides in reducing the numerous wires between a patient, monitoring systems, and associated displays.

**[0009]** Another advantage resides in an alternative for managing disease and outpatient care.

**[0010]** Still further advantages will become apparent to those of ordinary skill in the art upon reading and understanding the detailed description of the preferred embodiments.

**[0011]** FIG. **1** illustrates a cognitive (spectrum agile) device for receiving and selectively conveying signals from one or more monitoring devices residing within a wireless body network.

**[0012]** FIG. **2** illustrates an embodiment of the cognitive monitor having a cognitive monitor reasoner component that determines the signals to transmit.

**[0013]** FIG. **3** illustrates an exemplary embodiment of the cognitive monitor reasoner component.

**[0014]** FIG. **4** illustrates an embodiment of the cognitive radio having a cognitive radio reasoner component.

**[0015]** FIG. **5** illustrates an exemplary embodiment of the cognitive radio reasoner component.

**[0016]** FIG. **1** illustrates a cognitive (spectrum agile) device **2** for receiving and selectively conveying signals from one or more monitoring devices residing within a wireless body network. The cognitive device **2** includes a cognitive radio **4** that detects frequency spectrum **6** within a transmission range of a transmitter **8** of the cognitive device **2**. The cognitive radio **4** determines various characteristics (e.g., noise, total bandwidth, unused bandwidth, application, frequency range . . . ) of the detected spectrum and recommends a transmission spectrum (and protocol, power, coding scheme . . . ) for the transmitter **8** based at least in part on the characteristics. The characteristics define a bandwidth opportunity to transmit signals.

**[0017]** The selected transmission spectrum can be associated with various networks such as wireless a cellular network, a Wide Area Network (WAN), a Local Area Networks (LAN), a Metropolitan Area Network (MAN), a Campus Area Network (CAN), a Home Area Network (HAN), a Personal Area Networks (PAN), and the like. The cognitive radio **4** continuously (e.g., at some predefined rate) monitors spectrum and dynamically changes parameters (e.g., the transmission spectrum, protocol, coding scheme . . . ) based on interaction with the environment in which it operates. This interaction can involve active negotiation or communications with other spectrum users and/or passive sensing and decision making within the radio **4**. The cognitive radio **4** provides the transmission spectrum recommendation and the spectrum characteristics to a cognitive monitor **10**.

**[0018]** The cognitive monitor **10** is an intelligent system that decides what monitored information will be communicated by the transmitter **8**. The decision making involves understanding monitoring parameters, a patient's condition, and the environment. The cognitive monitor **10** receives information (e.g., sensed signals, personal information . . . ) from one or more sensors **12** or emitters **14** residing on an individual's body through a Body Area Network (BAN) **16**. The sensors **12** collect information such as an Electrocardiogram (ECG), an Electroencephalogram (EEG), an Electromyogram (EMG), a non-invasive blood pressure (NiBP), pulse, respirations, blood oxygen (SpO2), core body temperature, etc. The emitters **14** transmit an individual's identification, current medications, scheduled procedures, etc. In some aspects, devices (not shown) that sense environmental information communicate such information to the BAN.

**[0019]** After collecting this information, the cognitive monitor **10** analyzes the signals. Such analysis includes fusion techniques such as verifying blood pressure using ECG signals to identify erroneous signals (artifacts), which are ignored or discarded. In addition, the analysis includes parsing the received information into one or more groups of related information such as grouping ECG signals, etc. Grouped signals are compared for consistency with each other, and signals deemed inconsistent with the group are discarded or ignored. The cognitive monitor **10** sorts these signals according to quality; artifact-free signals are deemed higher quality signals and signals with artifacts are deemed lower quality signals. In one example, the cognitive monitor **10** selects signals to transmit based on the sorted (or ranked) signals and the recommended transmission spectrum provided by the cognitive radio **4**. It is to be understood that the cognitive monitor **10** can receive and use additional information to facilitate selecting signals to transmit. The transmitter **8** sends the selected signals over the transmission spectrum. The cognitive device **2** monitors individuals in various states or conditions. For example, the cognitive device **2** monitors post-operative recovery patients, geriatric patients, mentally ill individuals, depressed individuals, infants susceptible to Sudden Infant Death Syndrome (SIDS), individuals prone to allergic reactions, etc. Non clinical applications include wellness monitoring using application specific modules depending on an individual's concerns.

**[0020]** The cognitive device **2** preferably employs a platform that is universal to different markets throughout the world. This enables the cognitive device **2** to operate as an "always on" monitoring device irrespective of the individual's location. Such pervasiveness allows alarm reporting to be tailored per-person and such alarms can be communicated throughout the world. The actual periodicity of operation (checking available spectrum, receiving signals from the BAN, transmitting signals . . . ) and quantity of information transmitted is individual specific. Factors considered when determining a duty cycle and volume of information include, but are not limited to, cost, location, sensed physiological signals, the individual's condition, channel noise, quality and reliability, interference, average length of time the spectrum remains unused, and available bandwidth. Examples of suitable modes of operation include continuous, on-demand and emergency only.

**[0021]** By way of example, the following description focuses on a cognitive device that is configured to monitor a post-operative patient. When the patient is at home, the cognitive device **2** leverages a low-use home wireless network (e.g., the patient's personal wireless network or a network in a neighboring house). Since such network commonly is associated with a relatively large percentage of unused bandwidth, signals deemed at least remotely relevant to the patient's recovery are conveyed to a monitoring system accessible to the monitoring clinicians. Depending on the procedure (e.g., coronary bypass surgery, ACL . . . ), the relevant signals are transmitted every couple minutes, hourly, daily, weekly, etc. When the patient is travelling in a vehicle, the transmission spectrum shifts to an available spectrum. In one instance, this new transmission spectrum is within a cellular network. Since such networks typically are high-use networks, the cognitive device **2** determines that only the most important of these signals should or can be transmitted. In addition, safety measures (e.g., internal memory, buffers . . . ) are activated for emergency situations such as when there is no suitable unused bandwidth available or when bandwidth being used by the cognitive device **2** is required by the owner of bandwidth. If while travelling in the vehicle a low-use or high-bandwidth spectrum becomes available, the cognitive device **2** increases the amount of signals and frequency with which they are sent. In another example, the patient needs to return to the hospital due to post-operative complications. When entering the hospital's coverage area, the cognitive device **2** transmits clinically relevant signals and patient information to expedite admitting and caring for the patient.

**[0022]** FIG. **2** illustrates an embodiment of the cognitive monitor **10** having a cognitive monitor reasoner component **18** that determines which signals to transmit. As noted previously, the cognitive monitor **10** receives signals indicative of physiological state, an individual's identification, the environment, etc., and selects which signals to transmit based on a signal ranking and the transmission spectrum. Such selection is accomplished through the cognitive monitor reasoner component **18**. For example, the physiological signals from the sensors **14** are analyzed by a ranking component **20**. This analysis includes distinguishing clinically viable signals (artifact-free signals) from erroneous signals (artifacts), and sorting the signals based on quality. The ranking component **20** provides the ranked signals to the cognitive monitor reasoner component **18**. Concurrently, the cognitive radio **4** determines various characteristics (e.g., noise, bandwidth, unused bandwidth, application, frequency range . . . ) of detected frequency spectrums and provides the cognitive monitor reasoner component **18** with one or more recommendations of available spectrum for transmission by the transmitter **8**. The cognitive radio **4** also provides the spectrum characteristics to the cognitive monitor reasoner component **18**. It is to be appreciated that such information can be expressed in XML.

**[0023]** The cognitive monitor reasoner component **18** can receive and use additional information to facilitate determining which signals to transmit. For instance, in one embodiment the cognitive monitor reasoner component **18** receives environmental characteristics **22** describing the current usage environment. Such characteristics captures information about location, time, temperature, inputs from a variety of sensors, and information describing the circumstances (e.g., ambulance, home, office, emergency room . . . ) and so forth. In another embodiment, the cognitive monitor reasoner component **18** checks monitoring capabilities of the monitoring devices within the BAN and at a destination. These capabilities describe monitoring devices such as Fetal Transducer Unit, and can be described using the Composite Capabilities/Preference Profile (CC/PP) recommendation from World Wide Web Consortium (W3C).

**[0024]** In yet another embodiment, the cognitive monitor reasoner component **18** receives application requirements **26** describing relationships amongst different monitoring data. For example, the application requirements **26** can describe rules that facilitate determining the data to communicate under particular circumstances. For instance, the rules may indicate all sensed or monitored data should be communicated if available unused bandwidth surpasses a defined threshold, or only the SpO2 and one ECG lead data should be sent if the available unused bandwidth is within a particular range. The rules can be tailored to an attending clinician such that when that clinician monitors the individual, signals deemed clinically relevant to that clinician will be readily available. Furthermore, these requirements capture clinical constraints based on interaction amongst organs and patient's conditions. For instance, it will capture the relationship between ECG and SpO2, ECG and blood pressure, and blood pressure and SpO2. These requirements can be expressed in a Web Ontology language (OWL) recommendation from W3C.

**[0025]** It is to be appreciated that any or all of this information described above can be stored within the cognitive monitor **2**. For instance, the information can be stored within internal RAM or ROM. The information can also be retrieved by the cognitive monitor **2** or communicated to the cognitive monitor **2** when requested.

**[0026]** The cognitive monitor **2** uses the signal ranking provided by the ranking component **20**, the bandwidth recommendation by the cognitive radio **4**, the monitoring capabilities **24**, the application requirements **26**, the environmental characteristics **22**, and, optionally, other inputs to determine which signals the transmitter **8** will transmit.

**[0027]** FIG. **3** illustrates an exemplary embodiment of the cognitive monitor reasoner component **18**. As depicted, the cognitive monitor reasoner component **18** includes an inference engine **28** and a set of rules **30**. The inference engine **28** draws inferences from the information received by the cognitive monitor reasoner component **18** (ranked signals, available transmission spectrum, environmental, characteristics, monitoring capabilities, application requirements . . . ) based on the rules **30**. Such inferences determine which signals will be transmitted by the transmitter **8**. It is to be appreciated that the inference engine **28** can be a JESS rules engine (a JAVA based rules engine), a neural network, a support vector machine (SVM), a Bayesian classifier, and the like. In addition, the rules **30** include representations of algorithms that a device will employ and can be modelled using Protégé.

**[0028]** FIG. **4** illustrates an embodiment of the cognitive radio **4** having a cognitive radio reasoner component **34**. As described above, the cognitive radio **4** recommends one or more transmission spectrum, transmission protocols, coding schemes, etc. for the transmitter **8** based on spectrum characteristics such as noise, total bandwidth, unused bandwidth, application, frequency range, etc. The cognitive radio reasoner component **34** uses various information to determine this transmission spectrum. For example, in one embodiment the cognitive radio reasoner component **34** uses an FCC policy description **36**, which describes the constraints on transmission parameters to limit the level of interference perceived by primary radio systems in the respective area close to the secondary radio system. Such policy typically is represented in the OWL language. In another embodiment, the cognitive radio reasoner component **34** take into consideration device capabilities **38** that describe the characteristics and limitations of the device such as its source of electrical power, CPU, memory, frequency range, channelization, modulation and coding scheme, and communication protocols, for example. Such capabilities can be described using the CC/PP recommendation from W3C.

**[0029]** In yet another embodiment, current transmission/reception (Tx/Rx) conditions **40**, which describe the feedback from Media Access Control (MAC) and physical layers about the condition of the transmission environment (noisy, low chatter, . . . ), are analyzed by the cognitive radio reasoner component **34**. Measurement results can be provided through known measurement reports such as defined in the IEEE 802.11h and IEEE 802.11k standards using the OWL language. In still another embodiment, radio domain knowledge **42** is made accessible to the cognitive radio reasoner component **34**. The radio domain knowledge **42** is a repository of knowledge about the domain of radio communication. Examples of such knowledge includes: algorithms for spectrum opportunity management typically require information about how transmission parameters such as transmission power, frequency, maximum distances between communicating radio devices, modulation technique and coding scheme, etc. are related to each other. The cognitive radio reasoner component **34** may have to know that if the device increases the transmission power, the detection range increases (the distance to the intended receiving device increases), and at the same time the level of interference that other radio devices would observe increases as well.

**[0030]** The cognitive radio reasoner component **34** uses the above information to recommend to the cognitive monitor **8** a transmission frequency spectrum for the transmitter **8**. This recommendation describes parameters for transmission such as frequency, maximum allowed power, coding scheme, a protocol, etc. This information can be represented as an XML document/string, provided to the cognitive monitor **10**, and used by the cognitive monitor reasoner **18** of the cognitive monitor **10** as described above.

**[0031]** FIG. **5** illustrates an exemplary embodiment of the cognitive radio reasoner component **34**. The cognitive radio reasoner component **34** includes an inference engine **44** and a set of rules **46**. The inference engine **44** draws inferences from the information received by the cognitive radio reasoner component **34** (e.g., FCC policies, device capabilities . . . ) based on the rules **46**. These inferences facilitate recommending transmission spectrum for use by the cognitive monitor **10**. The inference engine **44** can be a JESS rules engine (a JAVA based rules engine), a neural network, a support vector machine (SVM), a Bayesian classifier, and the like. In addition, the rules **46** include representations of algorithms that a device will employ and can be modelled using Protégé.

**1**. A patient monitoring system, comprising:

a body network including:

at least one sensor that senses physiological information about a patient, and a cognitive device for communicating the physiological information to a remote location, the cognitive device including:

a cognitive radio that checks detected frequency spectra for unused bandwidth and recommends one or more bands on which to transmit clinically relevant information received from the body network to the remote location;

a cognitive monitor that receives the information from the body network, prioritizes the information based at least in part on a set of rules, and selects which information to transmit based on the prioritization and the recommended transmission bands; and

a transmitter that transmits the selected information as a function of priority over at least one or the recommended transmission bands.

**2**. The patient monitoring system as set forth in claim **1**, wherein the cognitive radio selects the transmission bands from the spectrum based in part on at least one of noise and quantity of unused bandwidth available.

**3**. The patient monitoring system as set forth in claim **1**, wherein the information received from the body network includes at least one of an Electrocardiogram, an Electroencephalogram, an Electromyogram, a non-invasive blood pressure, pulse, respirations, blood oxygen, and core body temperature.

**4**. The patient monitoring system as set forth in claim **1**, wherein the cognitive monitor parses the received information into one or more groups of related information.

**5**. The patient monitoring system as set forth in claim **4**, wherein the cognitive monitor compares the related information within a group for consistency and discards inconsistent information.

**6**. The patient monitoring system as set forth in claim **1**, wherein the cognitive monitor determines a level of noise in the received information and prioritizes the information from information with the least amount of noise to the information with the greatest amount of noise.

**7**. The patient monitoring system as set forth in claim **1**, wherein the cognitive monitor determines a degree of artifact in the received information and prioritizes the information from information with the least artifact to the information with the greatest artifact.

**8**. The patient monitoring system as set forth in claim **1**, wherein the set of rules prioritize the received information based on at least one of: a person's known physiological condition; clinical events deemed relevant to a monitoring clinician; and a predetermined priority defined by an administering clinician.

**9**. The patient monitoring system as set forth in claim **1**, wherein the cognitive radio continuously checks available frequency bands and dynamically updates the cognitive monitor with a band to use for transmission.

**10**. The patient monitoring system as set forth in claim **9**, wherein the cognitive monitor periodically analyzes the information remaining to be transmitted and the current transmission band, and re-prioritizes the information for transmission.

**11**. The patient monitoring system as set forth in claim **1**, the cognitive monitor includes:

a reasoner component that analyzes spectrum characteristics to which spectrum to recommend as transmission spectrum.

**12**. The patient monitoring system as set forth in claim **11**, the characteristics include at least one of noise, total bandwidth, unused bandwidth, application, and frequency range.

**13**. The patient monitoring system as set forth in claim **11**, the reasoner component includes:

a set of rules representing algorithms; and

an inference engine that draws inferences from at least one of a FCC policy, a device capability, a current transmission/reception condition, and radio domain knowledge based on the rules.

**14**. The patient monitoring system as set forth in claim **1**, the cognitive monitor includes:

a ranking component that ranks the information received from the body network based on quality;

a reasoner component that selects which signals to transmit based on the ranked information and the transmission spectrum.

**15**. The patient monitoring system as set forth in claim **14**, the reasoner component further bases its decision on at least one of a monitoring capability, an application requirement, and an environmental characteristic.

**16**. The patient monitoring system as set forth in claim **14**, the reasoner component includes:

a set of rules representing algorithms; and

an inference engine that draws inferences from one or more of a monitoring capability, an application requirements, an environmental characteristic, and a recommended transmission spectrum based on the rules.

**17**. A cognitive device for use in the patient monitoring system as set forth in claim **1**.

**18**. A cognitive device that facilitates monitoring information form-a wireless network, comprising:

a cognitive radio that checks detected frequency spectrum for unused bandwidth and recommends one or more bands for transmitting clinically relevant information received from the wireless network to a monitoring system;

a cognitive monitor that receives the information from the wireless network, prioritizes the information based at least in part on a set of rules, and selects which information to transmit based on the prioritization and the recommended transmission bands; and

a transmitter that transmits the selected information as a function of priority to the monitoring system over at least one or the recommended transmission bands.

**19**. A method for conveying physiological information received from a body network, which senses the physiological information, to a remote location, comprising:

receiving one or more physiological information carrying signals from the body network;

grouping the signals based on type;

prioritizing the signals within each group;

prioritizing the groups;

locating frequency bands with at least a portion of bandwidth available for transmitting the signals, and selecting a transmission band based oil qualitative and quantitative transmission characteristics;

selecting one or more of the signals to transmit based on signal priority and the band characteristics; and

transmitting the selected signals over the selected band to the remote location.

**20**. A cognitive computer device programmed to perform the method of claim **19**.

* * * * *

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| 专利名称(译) | 无线医疗监护设备 | | |
| 公开(公告)号 | US20080194925A1 | 公开(公告)日 | 2008-08-14 |
| 申请号 | US11/913496 | 申请日 | 2006-04-28 |
| [标]申请(专利权)人(译) | 皇家飞利浦电子股份有限公司 | | |
| 申请(专利权)人(译) | 皇家飞利浦电子N. V. | | |
| 当前申请(专利权)人(译) | 皇家飞利浦电子N. V. | | |
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| IPC分类号 | A61B5/00 | | |
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| 外部链接 | Espacenet USPTO | | |


摘要(译)

本文描述了一种患者监测系统，其包括身体网络（16），其具有至少一个传感器（12），其感测关于患者的生理信息;以及认知装置（2），用于将生理信息传送到远程位置。认知设备包括认知无线电（4），认知监视器（10）和发射器（8）。认知无线电设备（4）检查检测到的未使用带宽的频谱（6），并推荐一个或多个频带，在该频带上将从身体网络（16）接收的临床相关信息发送到远程位置;认知监视器（10）从身体网络（16）接收信息，至少部分地基于一组规则（30）对信息进行优先级排序，并基于优先级和推荐的传输频带选择要传输的信息;发送器（8）发送所选择的信息作为优先于至少一个或推荐的传输频带的连接点。