Wireless Body Area Network & ITS APPLICATION

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ABSTRACT : *WBAN based medical-health technologies have great potential for continuous monitoring in ambulatory settings, early detection of abnormal conditions, and supervised rehabilitation. They can provide patients with increased confidence and a better quality of life, and promote healthy behavior and health awareness. Continuous monitoring with early detection likely has the potential to provide patients with an increased level of confidence, which in turn may improve quality of life. In addition, ambulatory monitoring will allow patients to engage in normal activities of daily life, rather than staying at home or close to specialized medical services. Last but not least, inclusion of continuous monitoring data into medical databases will allow integrated analysis of all data to optimize individualized care and provide knowledge discovery through integrated data mining. Indeed, with the current technological trend toward integration of processors and wireless interfaces, we will soon have coin-sized intelligent sensors. They will be applied as skin patches, seamlessly integrated into a personal monitoring system, and worn for extended periods of time.*

Keywords : *WBAN, GPS, PDA, BAN.*

1. INTRODUCTION

WBAN or BAN, short for (Wireless) Body Area Network, consists of a set of mobile and compact intercommunicating sensors, either wearable or implanted into the human body, which monitor vital body parameters and movements. These devices, communicating through wireless technologies, transmit data from the body to a home base station, from where the data can be forwarded to a hospital, clinic or elsewhere, real-time[1][2]. A Body Area Network is a network containing sensor nodes in close proximity to a person's body monitoring vital signals of the human body and a more intelligent node capable of handle more advanced signal processing.

A Wireless Body Area Network (WBAN) connects independent nodes (e.g. sensors and actuators) that are situated in the clothes, on the body or under the skin of a person. The network typically expands over the whole human body and the nodes are connected through a wireless communication channel[3]. A Wireless Body Area Network (WBAN) consists of several small devices close to, attached to or implanted into the human body. These devices communicate by means of a wireless network. Interaction with the user or other persons is generally handled by a central device, e.g. a PDA.

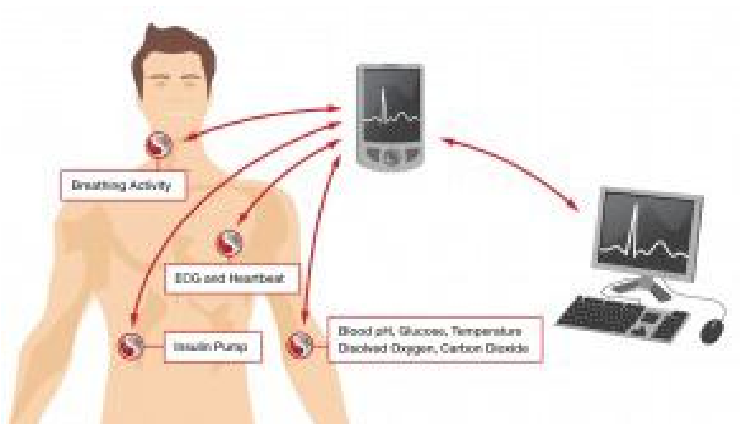


Figure1: Body area network [4]

Our era is witnessing an increasing pressure on quality and quantity of healthcare due to the increase of aging population, chronic diseases, and health consciousness of people. People put more attention in prevention and early risk detection. In US and European countries, retired parents usually do not live with their children. A system that can continuously monitor the health condition of elderly people and share information with remote care providers or hospitals will be in great demand. As an effort of catching this trend, body area network (BAN) as an emerging technology for providing this kind of health information, has been attracting more and more attentions recently. IEEE has launched the IEEE 802.15 Task Group 6 (BAN) in November 2007 to develop a communication standard optimized for low power devices, and operating on, in or around the human body to serve a variety of applications including medical and consumer electronics. In more common terms, a Body Area Network will be a network containing sensor nodes in close proximity to a person's body monitoring vital signals of the human body and a more intelligent node capable of handle more advanced signal processing. Although the most obvious application of BAN is in the medical sector there are also more recreational uses to BAN. By this convenient means, elderly people can keep track of their health conditions without frequent visits to their doctors' offices. Meanwhile, their doctors can still access the data and give their patients advices based on these data.[5]

1.1 STANDARD USED IN WBAN:

a) Bluetooth.

b) Zigbee.

c) Wireless LAN.

d) Radio frequency transceiver.

e) Cellular phone.

Power consumption must be reduced below 100ìW for radio interface. But today's low power radios such as Bluetooth and Zigbee cannot meet this stringent requirement. The emerging Ultra-Wide Band (UWB) technology shows strong advantages in reaching this target. First, most of the complexity of an UWB system is in the receiver, which is a perfect scenario in the WBAN context. Second, the very little hardware complexity of an UWB transmitter offers the potential for low-cost and highly integrated solutions. Finally, in a pulse-based UWB scheme, the transmitter can be duty-cycled at the pulse rate, thereby reducing the baseline power consumption. We present a low-power UWB transmitter that can be fully integrated in standard CMOS technology. Measured performances of the pulse generator are provided, showing the potential of UWB for low power and low cost implementations [6].

The rest of the paper is organized as follows. Section 2 discusses wireless body area network. The functional level of WBAN is discussed briefly in Section 3. Design issue has been discussed in Section 4. Applications have been discussed in Section 5. Finally, we conclude our work in Section 6.

2. WBAN

WBAN network consist of two types of nodes i.e. several devices or sensors can be attached to body by two methods.

a) Implanted node.

b) On-body node (i.e. external).

These nodes are placed in a star or multihop topology. But star topology is preferred. With the star topology there are two communication methods, which are beacon mode and non-beacon mode. In beacon mode, communication is controlled by the network coordinator, which transmits beacons for device synchronization and network association control. The network coordinator defines the start and end of a super frame by transmitting a periodic beacon. The length of the beacon period and hence the duty cycle of the system can be defined by the user between certain limits as specified in the standard.

In non-beacon mode, a network node can send data to the coordinator, by using CSMA/CA if required. To receive the data from the coordinator the node must power up and poll the coordinator. The advantage of non-beacon mode is that the node's receiver does not have to regularly power-up to receive the beacon. The disadvantage is that the nodes must wake up to receive the beacon and the coordinator cannot communicate at anytime with the node but must wait to be invited by the node to communicate.

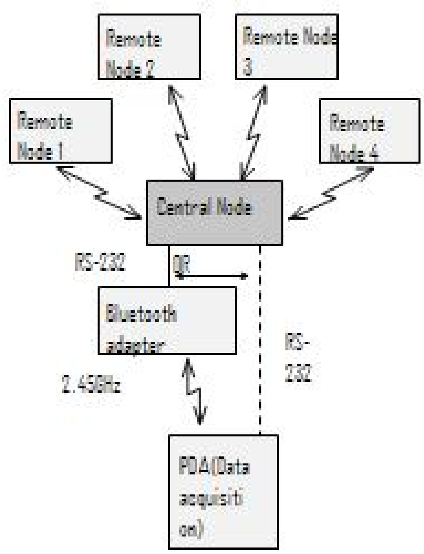


Figure2: The overall WBAN topology [7].

The overall WBAN topology is shown in Fig. 2. The central node receives acceleration data from all the remote nodes, and forwards both its own and the received data to the data acquisition PDA. A Bluetooth connection (F2M01 serial-to-Bluetooth adapter) with up to 100m range is used for this data link. As an option, a wired RS-232 link can be used.[7].

3. FUNCTIONAL LEVELS OF WBAN

The WBAN system is divided into three levels. The lowest level consists a set of intelligent sensors or nodes. These are the reduced function devise. These can only communicate with their parent device and cannot act as parent. The second level is the personal server (Internet enabled PDA, cell-phone, or home computer). These are full function devices. And they can communicate with their children as well as with the external network. The third level encompasses a network of remote server which is the remote application to which data or information is transferred.

Continuous technological advances in integrated circuits, wireless communication, and sensors enable development of miniature, non-invasive physiological sensors that communicate wirelessly with a personal server and subsequently through the Internet with a remote emergency, weather forecast or medical database server; using baseline (medical database), sensor (WBAN) and environmental (emergency or weather forecast) information, algorithms may result in patient-specific recommendations. The personal server, running on a PDA or a 3 G cell phone, provides the human-computer interface and communicates with the remote server(s). Figure 3 shows a generalized overview of a multi-tier system architecture; the lowest level encompasses a set of intelligent physiological sensors; the second level is the personal server (Internet enabled PDA, cell-phone, or home computer) and the third level encompasses a network of remote health care servers and related services (Caregiver, Physician, Clinic, Emergency, Weather). Each level represents a fairly complex subsystem with a local hierarchy employed to ensure efficiency, portability, security, and reduced cost illustrates an example of information flow in an integrated WBAN system.[8][9].

3.1 Sensor level

WBAN can include a number of physiological sensors depending on the end-user application. Information of several sensors can be combined to generate new information such as total energy expenditure. An extensive set of physiological sensors may include the following:

- An ECG (electrocardiogram) sensor for monitoring heart activity.
- An EMG (electromyography) sensor for monitoring muscle activity.
- An EEG (electroencephalography) sensor for monitoring brain electrical activity.
- A blood pressure sensor.
- A tilt sensor for monitoring trunk position.
- A breathing sensor for monitoring respiration.
- Movement sensors used to estimate user's activity.

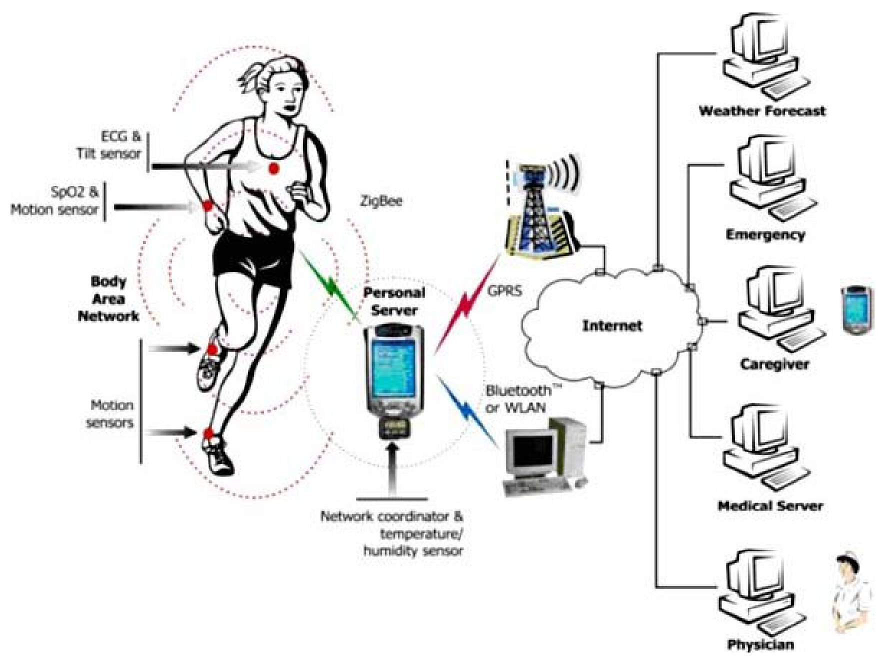


Figure3: Wireless Body Area Network of Intelligent Sensors for Patient Monitoring [8]

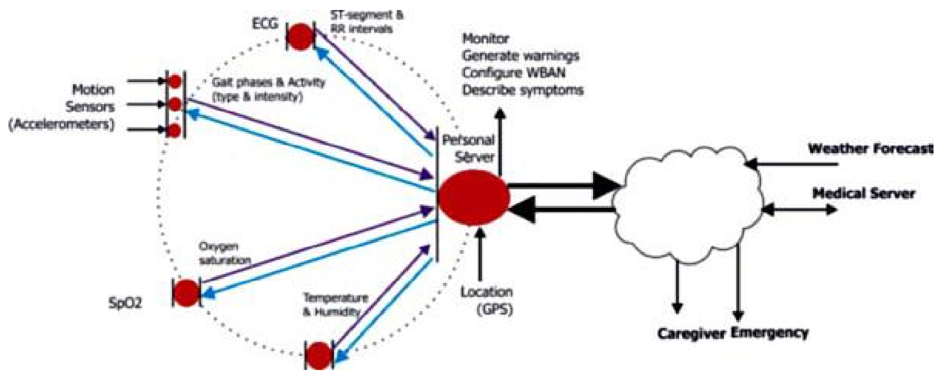


Figure4: Data flow in an integrated WBAN [9]

- A "smart sock" sensor or a sensor equipped shoe insole used to delineate phases of individual steps.

These physiological sensors typically generate analog signals that are interfaced to standard wireless network platforms that provide computational, storage, and communication capabilities.

3.2 Personal server level

The personal server performs the following tasks:

- Initialization, configuration, and synchronization of WBAN nodes.
- Control and monitor operation of WBAN nodes.
- Collection of sensor readings from physiological sensors.
- Processing and integration of data from various physiological sensors providing better insight into the user state.
- Providing an audio and graphical user-interface that can be used to relay early warnings or guidance (e.g., during rehabilitation).
- Secure communication with remote healthcare provider servers in the upper level using Internet services.

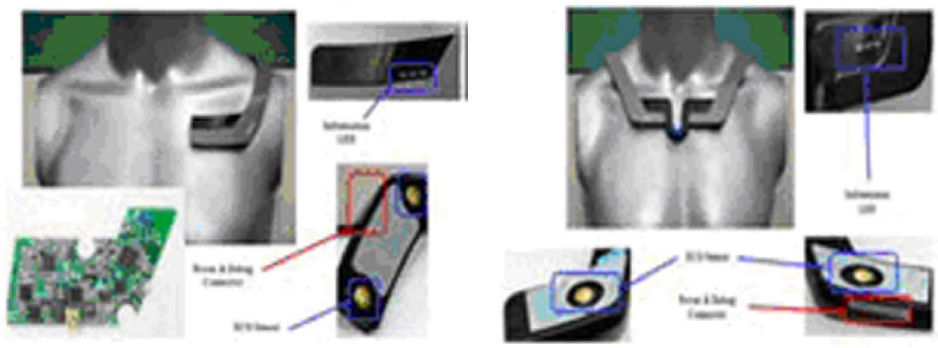
The personal server can be implemented on an off-the-shelf Internet-enabled PDA (Personal Digital Assistant) or 3 G cell phone, or on a home personal computer. Multiple configurations are possible depending on the type of wireless network employed. For example, the personal server can communicate with individual WBAN nodes using the Zigbee wireless protocol that provides low-power network operation and supports virtually an unlimited number of network nodes. A network coordinator, attached to the personal server, can perform some of the pre-processing and synchronization tasks. Other communication scenarios are also possible. For example, the personal server running on a Bluetooth or WLAN enabled PDA can communicate with remote upper-level services through a home computer; the computer then serves as a gateway.[8][9].

3.3 Medical service level

- **An emergency service**: If the received data are out of range or indicate an imminent medical condition.
- **The exact location of the patient**: If the personal server is equipped with GPS sensor.
- **Monitoring the activity of the patient**: By medical professionals.

We developed several type wearable physiological signal devices as shown in figure 5.Our strategy is that every possible physiological signal instruments is built into a physiological signal device and a central processor supervise the operation of each component, analyzes the measured data and then rapidly transfer these data using WBAN such as ZigBee.[10].

wrist watch type *chest belt type*



shoulder type *necklace type*

Figure5: wearable physiological signal devices [10].

4. DESIGN ISSUES

There are certain issues which have to be considered while designing a WBAN system.

4.1 Types of nodes:

The nodes can be motion & position sensors such as accelerometers, health monitoring sensors such as ECG, EMG, hearing of visual aid and environment sensors such as oxygen, pressure or humidity sensors. Accelerometers and gyroscopes offer greater sensitivity and are more applicable for monitoring of motion since they generate continuous output.

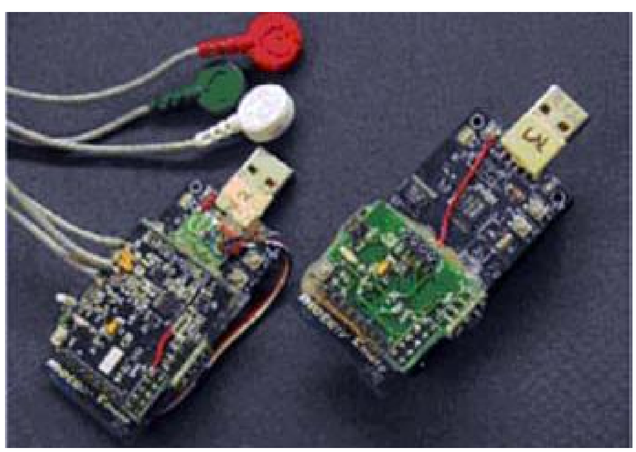


Figure 6: ECG & Motion Sensor [9].

Sampling rate for the sensor node:

It is found that the human induced activity has frequency between 0 to 18 or 30 Hz. So the sample rate of 10 to 100 Hz is considered to be sufficient without loosing any information.

4.2 Power source:

Sensors have to be extremely power efficient, because most of the WBAN sensors are battery operated and are required to last long without any need of maintenance. The other thing is that the WBAN consists of fairly large number of devices so frequent battery changes for multiple WBAN sensors would likely hamper user's acceptance and increase the cost. In addition, if we think about implantable sensors, low power consumption is very important. These kinds of sensors would ideally be self-powered, using energy extracted from the environment.

4.3 Size and weight of sensors:

To be unobtrusive, the sensors must be lightweight with small form factor. The size and weight of sensors is predominantly determined by the size and weight of batteries. Requirements for extended battery life directly oppose the requirement for small form factor and low weight.

4.4 Sensor Node Identification & Association:

The node is identified by the device ID which is unique for each device, but still there are some issues related to identifying the device related to a specific task. Such that if we have two motion sensors, one to monitor hand movement and the other to monitor foot 3 3 movement. Then how the server will know which one is mounted on the foot and which one is at hand? There are several ways to cope with this problem. One is that we manually enter the device ID of the sensor mounted at hand for the task of hand movement monitoring or we can use a systematic procedure for device recognition which is explained as follows. The user is given a list of instructions which ask the user to stimulate the sensors at a pre-defined pattern. And by monitoring the activity level of every sensor, the server will know which device is activated for what instruction and will assign it to the respective task.[9].

4.5 Sensor Node Calibration:

There are two type of calibrations for the sensor nodes. One is sensor calibration which is to accommodate sensor-to-sensor variations. When a sensor is replaces or newly added to the network, it must be calibrated according to the requirement. This type of calibration is needed only one time but it is necessary for sensor preparation. Exact nature of the calibration is sensor dependent. The other type is session calibration which is required immediately prior starting a new monitoring session to calibrate the sensor in the context of its current environment. This is also sensor dependent. Some sensor may need it and some may not.

4.6 Sensor location and mounting:

Although the purpose of the measurement does influence sensor location, researchers seem to disagree on the ideal body location for sensors. e.g. A motion sensor attached to an ankle is the most discriminative single position for state recognition, now they are using position recognition sensors at back (waist line), in thigh pocket, wrist and are able to accurately monitor a subject's activity and with the assistance of gyroscopes and compass they are able to successfully estimate a subject's change in location. Sensor attachment is also a critical factor, since the movement of loosely attached sensors creates spurious oscillations after an abrupt movement that can generate false events or mask real events.

4.7 Seamless system configuration:

The intelligent WBAN sensors should allow users to easily assemble a robust ad-hoc WBAN, depending on the user's state of health. The user should be able to use "off-the-shelf" sensors, manufactured by different companies, and sold "over-the-counter". Each sensor should be able to identify itself and declare its operational range and functionality. In addition, they should support easy customization for a given application.[11].

4.8 Intuitive and simple user interface:

The end users are not technicians or scientist or the user may be a handicap where the BAN is used as rehabilitation purposes. So the interface should be simple enough for the users to easily understand and handle properly.

4.9 Interference:

Almost all of the short range networks operate in the ISM range of frequency. Such as wireless LANs and Bluetooth. IEEE 802.11b/g wireless Ethernet operate in 2.4 GHz band and most of the microwave ovens operate at 2.45 GHz. So there is a big problem in the form of interference and we have to deal with it to implement an operational and secure WBAN. There can be interference between WBAN of one person and the other's if they are close enough. A WBAN can be configured to listen to only those devices which are part of the network by using device authentication. Biomedical signals which are unique for every person can be used for device authentication.[12][13].

5. APPLICATIONS

Initial applications of WBANs are expected to appear primarily in the healthcare domain, especially for continuous monitoring and logging vital parameters of patients suffering from chronic diseases such as diabetes, asthma and heart attacks. A WBAN network in place on a patient can alert the hospital, even before he has a heart attack, through measuring changes in his vital signs. A WBAN network on a diabetic patient could auto inject insulin though a pump, as soon as his insulin level declines, thus making the patient 'doctor-free' and virtually healthy.[16].

- Diabetes.
  –Glucose monitoring and insulin release.
- Implanted ECG monitoring and arrhythmia alarming system.
- Hypertension.
  –Continuous in vivo bloody pressure monitoring and regulation system.
- Spinal cord injuries.
  –Bladder pressure sensor.
  –Micro stimulator.
- Animal experiment for new drug design.[17].

Other applications of this technology include sports, military, or security. Extending the technology to new areas could also assist communication by seamless exchanges of information between individuals, or between individual and machines. Imagine businesspeople exchanging business cards, just with a handshake, with the help of BAN sensors. These applications might become reality with the WBAN implementation very soon.

A WBAN offers many promising new applications in the area of remote health monitoring, home/health care, medicine, multimedia, sports and many other, all of which make advantage of the unconstrained freedom of movement a WBAN offers. In the medical field, for example, a patient can be equipped with a wireless body area network consisting of sensors that constantly measure specific biological functions, such as temperature, blood pressure, heart rate, electrocardiogram (ECG), respiration, etc. The advantage is that the patient doesn't have to stay in bed, but can move freely across the room and even leave the hospital for a while. This improves the quality of life for the patient and reduces hospital costs. In addition, data collected over a longer period and in the natural environment of the patient, offers more useful information, allowing for a more accurate and sometimes even faster diagnosis.

The WBAN technology can be used for computer-assisted physical rehabilitation in ambulatory settings and monitoring of trends during recovery. An integrated system can synergize the information from multiple sensors, warn the user in the case of emergencies, and provide feedback during supervised recovery or normal activity. Candidate applications include post-stroke rehabilitation, orthopaedic rehabilitation (e.g. hip/knee replacement rehabilitation), and supervised recovery of cardiac patients. In the case of orthopaedic rehabilitation the system can measure forces and accelerations at different points and provide feedback to the user in real-time. Unobtrusive monitoring of cardiac patients can be used to estimate intensity of activities in user's daily routine and correlate it with the heart activity.

In addition, WBAN systems can be used for gait phase detection during programmable, functional electrical stimulation, analysis of balance and monitoring of Parkinson's disease patients in the ambulatory setting, computer supervision of health and activity status of elderly, weight loss therapy, obesity prevention, or in general promotion of a healthy, physically act.[5][17].

5.1 MEDICAL APPLICATIONS OF WBAN

Medical applications of WBAN cover continuous waveform sampling of biomedical signals, monitoring of vital signal information, and low rate remote control of medical devices . They can be broadly classified into two categories depending on their operating environments. One is the so-called wearable BAN, which is mainly operated on the surface or in the vicinity of body, such as medical monitoring. Another is the so-called implantable BAN, which is operated inside the human body, e.g. capsule endoscope and pacemaker.

A) NETWORK ARCHITECHTURE OF MEDICAL WBAN

In this study, the architecture under consideration is shown in Figure 7. This architecture consists of two main parts: multiple body sensor units and a body central unit. The body sensor units

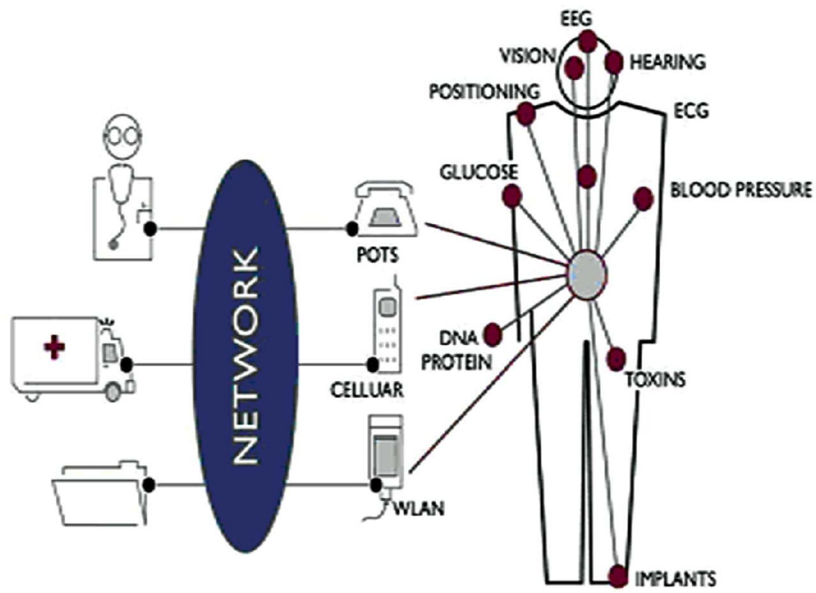


Figure 7: BAN architecture under consideration [6] [19].

perform vital medical data acquisition, data (pre-) processing, actuator control, data transmission and provide some basic user feedback. The body central unit links multiple sensor units, performs data collection, data processing/compression, actuator control, basic event detection/management and provides external access together with a personalized user interface. In our study, we will use the ECG signal as an example to evaluate its performance in healthcare environment. [18].

B) A PROTOTYPE WBAN SYSTEM WITH BLUETOOTH

From a general understanding of the BAN and the system requirements, it is evident that possible candidates in implementing BAN should be short range communication technologies. IEEE 802.15.1 Bluetooth operates in the 2.4GHz ISM band, from 2400MHz to 2483.5MHz .The system employs a frequency-hopping multiple access schemes to combat interference and fading. The symbol rate is 1 Msymbol/s supporting a bit rate of 1 Mb/s. For example, ECG signal from each channel are digitized at 360 Hz with 11-bit resolution implying a data rate of 3.84 Kbps per channel, so all 12 channels of ECG data can potentially be transmitted using Bluetooth. In addition, forward error correction (FEC) and automatic repeat request (ARQ) for retransmission are used as authentication of reception to ensure reliable communication. Based on its suitability of BAN, we test a prototype system for BAN using Bluetooth technology. We will discuss the detailed system in the following.[19].

C) System block diagram of WBAN

The whole system block diagram is in Figure 8. First, the digitized ECG signals are passed through the data compression module in order to reduce the transmission requirement and the needed storage capacity.

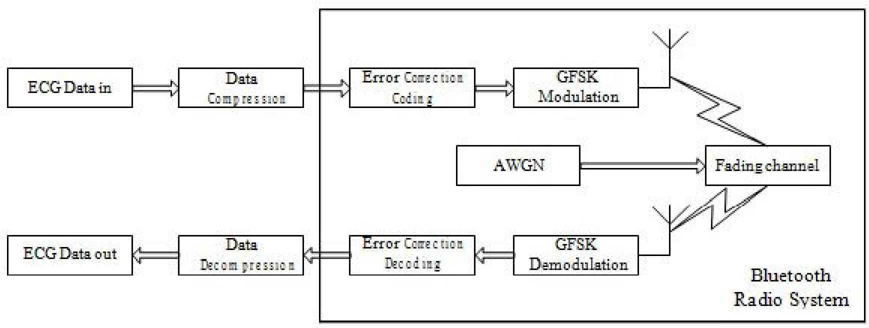


Figure 8: System block diagram [19].

Then the compressed data are transmitted through the Bluetooth Radio System module. The details of these modules are described in the following sections. At the receiver, the inverse processes are performed to reconstruct the original signals

ECG data compression:

By utilizing the ECG compression techniques, we expect to achieve the objective of reducing the amount of digitized ECG data as much as possible while preserving the diagnostic information in the reconstructed signal. The compression ratio (CR) is a measure of the compression performance, defined as the ratio between the number of bits needed to represent the original and the compressed signals. For the error criterion, the percentage root-mean-square difference (PRD) measure is employed. However, the clinical acceptability of the reconstructed signal should always be determined through visual inspection by physicians. Existing data compression techniques for ECG signals can be classified into three main categories: Direct data compression methods, transformation methods and parameter extraction methods. Based on the ECG data characteristics and implementation complexity, we choose the following schemes:

1. Split the original signal into M successive blocks, each having N samples.
2. Transform each block using discrete cosine transform (DCT).
3. Quantize of DCT coefficients.
4. Encode the quantized DCT coefficients using LZW coding.

Bluetooth radio system:

Modulation:

The modulation is Gaussian frequency shift keying (GFSK) with a bandwidth-bit period product, also known as bandwidth (BT), of 0.5. The modulation index may vary between 0.28 and 0.35.

Demodulation:

At the receiver, we use a simple differential demodulator. The complex base-band signal was sampled and multiplied by its complex conjugate that was delayed by a symbol period. The resulting differential phases of the symbols, *n n*"1 Ö "Ö are detected and decided that '1' was sent if *n n*"1 Ö " Ö was greater than or equal to zero and '0' was sent if *n n*"1 Ö "Ö was negative.[19][20].

6. CONCLUSION

WBAN based m-Health technologies have great potential for continuous monitoring in ambulatory settings, early detection of abnormal conditions, and supervised rehabilitation. They can provide patients with increased confidence and a better quality of life, and promote healthy behaviour and health awareness. Continuous monitoring with early detection likely has the potential to provide patients with an increased level of confidence, which in turn may improve quality of life. In addition, ambulatory monitoring will allow patients to engage in normal activities of daily life, rather than staying at home or close to specialized medical services. Last but not least, inclusion of continuous monitoring data into medical databases will allow integrated analysis of all data to optimize individualized care and provide knowledge discovery through integrated data mining. Indeed, with the current technological trend toward integration of processors and wireless interfaces, we will soon have coin-sized intelligent sensors. They will be applied as skin patches, seamlessly integrated into a personal monitoring system, and worn for extended periods of time.

Automatic integration of information from m-Health systems into research databases can provide medical community possibility of data mining of huge amounts of data. This will allow improved insights into disease evolution, the rehabilitation process, and the effects of drug therapy.

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