A Survey on Wireless Body Area Network

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Abstract- One of the most important emerging networks applicable in many fields is wireless body area networks (WBANS).In this paper we survey the wireless body area networks (WBANS) and their various applications in healthcare. In this paper a concise survey consisting of the various sections mainly focusing on the paramount aspect of WBANS and it applications in medicine to reduce the need for caregivers and to help the elderly and chronically ill people live an independent life.

***Index Terms*-** WBAN, Wireless Body Area Network, Body Sensor Network, Mobile Healthcare, WBAN Survey.

I. INTRODUCTION

As healthcare costs are rapidly increasing with the world's population, there has been a need to monitor a patient health status anywhere both in and out of the hospital. This demand and the advancement in technology in mobile electronic devices, wireless communication, portable batters, and sensors as led to the development of wireless body area network (WBANS). A wireless body area network (WBAN) is a network with a special purpose design to operate automatically can autonomously connect and interact with various medical appliances and sensors, which is located inside or outside the human body. Apart from cost reduction and flexibility applications of WBAN in health care will offer significant advantages such as mobility of patients since portable monitoring devices and sensors are being used and secondly WBAN uses location independent monitoring devices which are not there in the contemporary electronic monitoring systems furthermore WBAN can connect itself to the internet and transmit data to a remote database or server and WBAN application can also be extended into military and sport areas where the soldier or player health status can be monitored. The main purpose of this paper is to present a very comprehensive and concise survey on WBAN and it various applications within the healthcare industries. Section (2) presents WBAN sensing and monitoring application in various medical scenarios, Section (3) examines the WBAN system architectures, WBANS network designs techniques such as the power reliability and efficiencies of WBAN is presented in Section (4). Section (5) explores various approaches to routing in WBAN, security techniques and protocols of WBAN are being presented in Section (6). While Section (7) presents the future scope of WBAN and its conclusion.

II. SENSING AND MONITORING

Sensing and monitory digital devices that an individual can wear on the body and are based on wireless technology are already in existence. There can be in the form of smart cloth or bandages which allows the continuous monitoring of blood glucose levels, blood pressure and other biometric data Wearable biosensors are the non-obstructive devices that helps to overcome the limitations of ambulatory technology and also provide a fast and energetic response to the need of monitoring patients over a long period of time and it works even in a distant area. We will like to start with the already existing sensors, basically there are two types of sensors which are the wearable sensors and the implanted sensor both type of sensor biological device which as a physiochemical transducer used to produce an electronic signal which is equal to a single analysis which is transmitted a to a detector. These sensors are been designs with respect to the fact that the outcome must be improved while the cost and bulkiness of the sensor are reduce. The real world physiological data gotten from the sensor is being sent wirelessly to the internet which is then forwarded to the doctor so this helps in the optimization of the well being of the patient's wellness by making the medical progress better and easier in the collection and analysis of the patient data.

A. Smart shirt

A smart shirt is like a wearable mother board. Basically a smart shirt is a cloth made from smart fabric mainly used to allow remote physiological monitoring of various vital signs of the wearer such as respiration rate, heart rate, temperature, activity, and posture. Vivo Metrics is claimed that Life Shirt was the first commercially available smart shirt, and recorded ECG, respiration using inductance plethysmography, accelerometry with optional plug-in pulse oximetry, GSR, microphone blood pressure, and electronic diary capture. Information from the shirt may be stored locally, or transfer to the wearer's doctor, coach, or through a personal server such as a wireless network like RF, WLAN, Bluetooth or cellular network.

A typical example of a smart shit is the Georgia Tech Wearable Motherboard as shown in figure 1.0 below. It uses optical fibers to detect wounds from bullets and special sensors to monitor the vital signs of the body. The smart shirt is the best possible solution to sensing, monitoring and information processing devices. With the Georgia tech wearable motherboard the vital signs of human beings could be measured in an un-obstructive manner. It was woven into a single piece garment on the weaving machine to fit 38-40" chest.

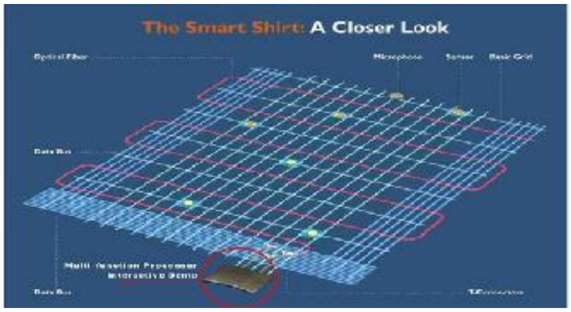

Fig.1. Georgia tech Smart Shirt (Wearable Motherboard)

The smart shirt technology shown in figure 2.0 has already led to an unobstructed and continuous monitoring for patients therefore play a major role in disease management such as heart disease, diabetes, high blood pressure ,chronic, depression by enabling early systematic intervention and bronchitis.

B. *Ring Sensor*

The ring sensor is a pulse oximetry sensor which helps in the continuous monitoring of oxygen saturation and heart rate in an un-obstructive manner. The ring sensor is a ring shaped device that can be worn for long periods comfortably. The ring sensor is made up of

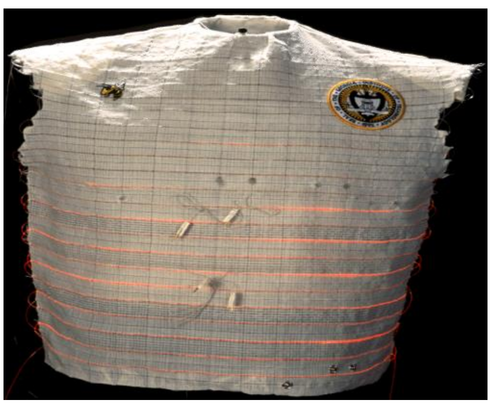

Fig.2 The Smart Shirt Technology

sensing devices like photodiodes, a transmitter, LED's and microprocessor in it. This sensor is made up of an optoelectric components which supports blood oxygen saturation non-invasively continuously and a long-term monitoring of the patient's arterial blood volume waveforms. These signals are transmitted to the doctor's computer for diagnosis of the patient's cardiovascular conditions. This system provides a continuous monitoring of the patient it provides unique and useful information for preventive diagnosis, which in long-term trends are more important.The ring sensor is design in such a way that the patient wear it comfortably 24 hous a day it is completely wireless. The principle of the ring sensor is mainly based on the contraction of the heart muscles Whenever the heart muscle contracts, then the blood is removed from the ventricles hence the transmission of pressure pulse takes place through the circulatory system. The displacement of vessel walls occur that that is measured to detect the changes in the blood volume when this pulse of pressure travels through the vessels.

The process is done by photoelectric method in which the photo conductors like photo resistors which are mainly used, then the amount of blood will increases in the finger when blood is forced to the extremities. It in turn changes the optical density and in turn reduces the light transmission through the finger and the resistance in the photoconductor increases. According to the increase of blood in the finger, a voltage divider circuit is connected with the photo resistor that produces a voltage that varies accordingly.

C. Activity/Motion Detection

An accelerometer is a sensor which can measures acceleration with respect to gravity, it can be used to determine the orientation of a body part even without movement hence The nature of motion and kind of activities an individual engages in can be detected by a system which combines a gyroscope with an accelerator Since a gyroscope is a sensor that helps to measure the angular velocity it can also be used to determine the orientation of a moving body.

D. Electroencephalography (EEG)

Electroencephalography (EEG) is simply the recording of electrical activity of the brain. In clinical enviroment, EEG is simply the recording of the brain's spontaneous electrical activity over a period of time, usually 28-43 minutes; Diagnostic applications mainly focus on the spectral content of EEG, that is basically the neural oscillations that can be observed in EEG signals. EEG measures the fluctuations voltage resulting from ionic current flows aroud the neuron of the brain. presently, ambulatory EEG (AEEG) recordings have been shown to have great value in the diagnosis of epilepsy and in the monitoring of patient response to therapy . Much of the information gotten from AEEG recordings may not be obtained during a routine, 20-min EEG test. This serves as motivation to develop wireless EEG sensors that will make there cording of AEEG signals during daily activities less obtrusive and less complicated.

E. Implantable Sensors

Implantable Neural Stimulators: Implantable neural stimulators send electrical impulses into the brain or spinal cord mainly use for the treatment of Parkinson's disease, intractable epilepsy and chronic pain. Spinal cord stimulation (SCS), in the simplest form, made up of stimulating electrodes, implanted in the epidural space, an electrical pulse generator, implanted usually in the lower abdominal area , conducting wires helps to connect the electrodes to the generator, and the remote control of the generator. Spinal cord stimulator is used mostly in treatment when failed back surgery syndrome occurs and complex regional pain syndrome.

III. WBAN SYSTEM ARCHITECTURES

In this section typical system architecture of a wireless body area network is presented with respect to its physical location, various network topology, applications and specific network design. A typical WBAN system architecture is made up of three main sections these are:

a. Wireless body area network(WBAN)
b. Personal server (PPS)

c. Medical sever for health monitoring system(MSHM)

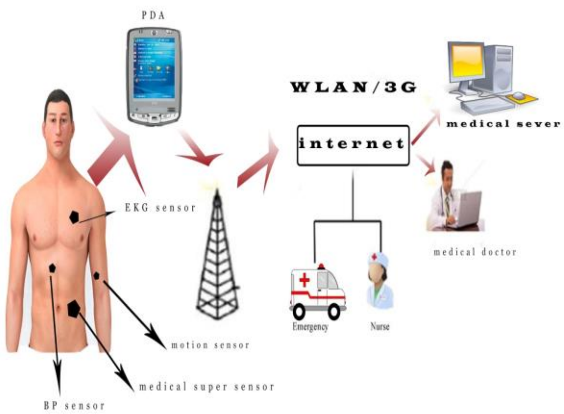

Fig.3 WBAN Architecture

in this section wearable sensors are being attached to the patent body this sensor will sense the necessary changes in health of the patient such ECG sensor, blood pressure sensor etc and providing a constant feedback to the healthcare monitoring system. the following are the most common main parts of the medical sensors.

A. *Radio trans-receiver*

A radio trans-receiver helps to transmit and receive sensed physiological data and it allso helps in communications between various nodes wirelessly

B. *Memory*

Helps to temporarly store the data that have sensed by the medical sensor.

C. *Micontroller/microproccessor*

Used to control the functionality of the component in the sensor node and also used local data processing

D.*sensor*

A sensor is the main chip which is used to sensed the physiological changes in the patient body and convert it into and electrical signals.

E. *Power supply*

Power supply happens to be a major factor in the medical sensor since it can easily affect the portability of the medical sensor. in the medical sensor batteries are normally used, this batteries can last up to several months even though a single sensor can sense and process many physiological signals at a time. a single battery power supply can power many sensors at a time such the electro- myogram(EMG) which is used for muscles monitoring activities, an electro cardio sensor (EKG) can also be used at the same time for monitoring the heart activities etc. This various sensors interacts with each other with the help of a local radio frequency while Zig-Bee can be used as the main communication protocol to communicate with the sever. in some cases a medical super sensor (MSS) is used to collect multiple samples of the sensed data from various body sensors and this reduces the amount of data that is to be transmitted by the BSNs because the Medical Super Sensors (MSS) helps to filter out all the redundant data. this in turn helps to improve the overall bandwidth utilization as well as a reduction in the power consumption of the BSs

F. *Personal server*

In this section the personal server uses a communication protocol with Zig-Bee to interfaces the WBAN nodes the setup is implemented on an Intelligent Personal Digital Assistant (IPDA). This keeps the authentication information of the patient and is configured with the medical server IP address in order to connect the medical services. It collects physiological vital signals from WBAN, when there is a sudden clinical change in the current patient health condition like changes in oxygen saturation, cardiovascular signals etc the transmission of critical data will be prioritizes and finally it processes it and forward it to the medical server. Moreover, the IPDA can perform the task of analyzing the physiological data intelligently and can also do a local reasoning to determine user's health status and provide feedback through a user friendly and interactive graphical user interface based on data received from MSS. A 3G communication protocol and other long range communications protocols such as GPRS and WWAN is used to connect personal server and the third tier together. In order to improve the overall quality of service for data transmission using IPDA, in terms of latency, band-width and power consumption a separated service based on two systems are showed. They are Data Compression and Priority Scheduling. In this method only the critical vital signs will transmit first while less critical signs are stored and transmit later this helps to reduces energy consumed by the IPDA during transmission.

G. *Medical Server for Healthcare Monitoring (*MSHM).

The Medical Server for Healthcare Monitoring (MSHM) receives data from the personal server, it is the backbone of the entire architecture. It is situated at a health care centers where medical services are provided like a clinic, hospital etc. MSHM keeps an electronic medical records (EMRs) of registered patients, which can be accessible by different medical staff in the medical center, this includes specialists, doctors and general practitioners from their offices in the medical center through the internet. MSHM is responsible for accepting data from various personal server, format the data and insert the received data into its EMRs and analyzing the data patterns. If the received data is out of range that is if there is a deviation from the normal threshold or an indication of a serious health anomalies condition, medical staff and doctors in the emergency unit can be notified to take necessary actions. if the patient is in an isolated area ,which is far away from the doctor and medical staffs a specialist doctor can observe the physiological data of the patient diagnose it, prescribe the necessary treatment and drugs for the patient. This information will sent back to the doctor in the isolated hospital through the internet. Moreover The MSHM also provides instructions to the patient, such as prescribed medications, exercises etc.

IV. WBANS NETWORK DESIGN ISSUES

Data transmission reliability and latency are very important in any WBAN which cololect non-critical and critical data from the various part of the human body. The reliability and latency of a WBAN will mainly depend on the design of the Medium Access Control layer and it physical design. The MAC layer helps to determine the network efficiency and utilization issues which mainly determine a system and operating costs of a WBAN. the design of the MAC layer also helps to determine the power consumption of a WBAN which is an important design issue. The physical layer also determines the reliability of the WBAN simultaneously.

A. Power efficiency

Power management is always an important operational issue in any design especially in WBAN. the power management in WBAN can be optimize by the PHY (physical) and the MAC (medium access control) layer processes. MAC layer introduces a much higher level of power saving by using several techniques such as packet transmission scheduling and channel access techniques it implements the use an intelligent signaling techniques and an optimal packet structure. By selecting appropriate modulation and coding techniques the PHY layer can increase the probability of successful transmissions. End to end packet delays and the power budget of a WBAN node can be reduce through a higher packet transmission probability.

B. Reliability

The reliability of WABN is directly proportional to the packet transmission delay and the packet loss probability. The probability of the packet loss is influence by the Bit Error Rate (BIR) of the MAC layer transmission procedures and that of the channel. by using an adaptive modulation and coding techniques which suites the channel conditions in which the transmission takes place the PHY layer of a WBAN can reduce the effective bit error rate of a transmission link. However the effective bit error rate can be reduce by implementing a forwards correcting error (EFR) technique. The use of this technique requires transmission of additional redundant bits which could increase the power budget of the WBAN node due to the transmission of extra bits. The situation of a network can also affect the can also affect the reliability and power budget of a WBAN. in order to transmit packets successfully when the interference and noise floor of a network is high a node needs to transmit at a very high transmitting power level.

C. Scalability

Scalability is very essential for a patient monitoring system such as WBAN because it is quiet often necessary to change the number of nodes and collect different physiological data from the patient body. when a WBAN is scalable it is easy for healthcare staffs to add or remove some nodes without affecting the entire WBAN operation. Since the PHY layers are fixed the scalability of WBAN is largely dependent on MAC layer this MAC layer plays a vital role in maintaining reliability under variable transmission and traffic conditions MAC layer also helps to maintain a good quality of service.

V. VARIOUS APPROACHES TO ROUTING IN WBAN

Frequent network partitioning due to postural mobility of the on-body sensors, , low transmission power of the sensors, high propagation loss across the human body and low reliability of end-to-end path from source to sink are the principal characteristics of a Wireless Body Area Network (WBAN) that make design of a routing protocol necessary. [1] Studied the Link layer behavior of WBANs at 2.4 GHz and observed the following:

(i) Environments do have an impact on PDR. In a lab setting more than 70% of links have PDR 90% or more; while in an open setting (on the roof) about 50% of links have 90% or more PDR.

(ii) Increasing transmission power at regions with low multipath increases PDR even more.

(iii) Average packet delivery ratio (PDR) increases with increase in transmission power.

The authors also found that channel symmetry is better in environments having more reflective surfaces (more multipath). Conventionally, there are mainly two approaches to routing in BANs. One approach is to design a routing layer on top of the MAC layer, where link qualities are measured based on selected parameters and taken into path computation the other is to implement the routing functions with the MAC layer, with a cross-layer approach.

The first approach has been investigated in [9] where the authors have proposed a probabilistic packet routing protocol, Probabilistic Routing with Postural Link Cost (PRPLC),using a stochastic link cost. The topology is being developed in the laboratory with on body sensor nodes using about 900 MHz Mica2Dot Motes operating in TinyOS. The motes consist of MTS 510 sensor cards from Crossbow Technologies and Chipcon's Smart RF CC1000 radio chips. The radio chips' transmission powers are decreased to set the range of transmission between 0.3 to 0.6 meters. The proposed protocol is based on postural link cost formulation using a time-varying cost, formulated for each link based on the area in the connectivity patterns of the links. The protocol uses postural link costs to compute probabilistic forwarding of data packets. The second approach has been studied and proposed in [3] Have proposed a cross-layer CICADA protocol that sets up a spanning tree and uses time slots for controlling each node's transmission and reception cycles. Each node tells its children about their turns for sending thier data. Data transfer takes place in a sequence of cycles: a data cycle and a control cycle. In the control cycle all nodes are informed about the order in of transmission. When all nodes receive their control schemes, that data cycle starts. In the data cycle each data scheme has two parts: a data period, and a waiting period. The data period also provides a contention slot to allow nodes to join the tree. This can provide mobility support for the network which helps nodes to get disconnected due to postural mobility also. The authors have also discussed the energy efficiency of the algorithm, which depends on the network topology. As the nodes have to spend time on idle listening and overhearing during the control cycle, depth of the tree plays a significant role in controlling the energy efficiency of the protocol.

VI. SECURITY PROTOCOLS OF WBAN

The WBAN and it infrastructure must implement a guarantee security operations with data integrity, confidentiality and privacy of the patients medical data. In addressing privacy issues in WBAN it must be ensured that the Health Insurance Portability and Accountability Act of 1996 (HIPAA) 1996 is observed.

Confidentiality: the network should be able to guarantee the secrecy of message exchange among nodes.

Data Integrity**:** it is needed to prevent the altering of data traversing the communication paths between nodes, and also to prevent replay attacks.

Privacy: The patients' data should not be disclosed to unauthorized entities. Medical information is one of the most sensitive forms of personal data.

Availability: Since this network carries highly sensitive, important and potentially life-saving information, it is of utmost importance that the network resources are available at all times.
Authentication: This is necessary to enable the WBAN to validate network nodes and thus prevent network compromise and/or node impersonation.

The below list shows the various emerging security approaches in WBANs.

A. *IEEE 802.15.4 Security*

Several security suites can be implemented under the IEEE 802.15.4. the security suite modes is classified mainly into two basic modes: the secured mode and unsecured mode. In the unsecure mode no security suite has been selected. The standard defines 8 distinct security suites .The first is the Null suite that provides no security at all. While the others can be further classified based on the various security properties they provide.The IEEE 802.15.4 Security Suites is given below:

Name	**Description**
Null	No security
AES-CTR	Encryption only. This provides access control, data encryption, and optional sequential freshness.
AES-CBCMAC-128 AES-BCMAC-64 AES-BCMAC-32	Authentication only allowing flexibility by the selection of different MAC lengths: 32, 64, 128 bits.
AES-CCM-128 AES-CCM-64 AES-CCM-32	This provides authentication and encryption allowing flexibility by the selection of different MAC lengths: 32, 64, 128 bits

Table.1. IEEE 802.15.4 Security Suites

C. *Hardware Encryption*

Hardware encryption is been implemented in a WBAN with off-the-shelf ZigBee platform but Not all the sensor node hardware have hardware encryption support. Hardware encryption can be implemented utilizing the ChipCon 2420 ZigBee compliant RF Transceiver. The CC2420 is able to execute IEEE 802.15.4 operations with AES encryption using 128-bit keys for security. These security operations consist of the counter (CTR) mode encryption and decryption, CCM encryption plus authentication and CBC-MAC authentication.

D. *Tiny Sec*

Tiny Sec is very popular in the wireless sensor community and has even been implemented on a variety of custom hardware. It is a software based security architecture that implements link-layer encryption. It is a component of the official Tiny OS release. Tiny Sec encrypts the data packet with a group key common to the sensor nodes and computes a message authentication code (MAC) for the entire packet including the header. This group key is shared network-wide and manually programmed into the nodes prior to deployment. This network-wide key presents a single point of vulnerability. Tiny Sec does not protect against node capture.

E. *ZigBee Security Services*

ZigBee defines a new standard for ultra-low power wireless communication.The ZigBee network layer (NWK) is designed to operate on top of the IEEE 802.15.4 defined PHY and MAC layers. The ZigBee standard defines extra security services including processes for key exchange and authentication. ZigBee standard specifies a "Trust Center". which performs it functions by the ZigBee coordinator. The Zigbee coordinator is responsible for joining the network and the distribution of keys.

F. Biometrics

Biometrics presents itself as a useful mechanism to use in the key establishment and Authentication of body sensor nodes .This processes uses measurement of physiological Characteristics of the body itself as a parameter in a symmetric key management system. The necessary characteristics for a useful biometric physiological value are presented below:

- Invulnerable: difficult to compromise
- Acceptable: adoption by the public
- Time variance: changes over time
- Effective: able to implement a relatively secure biometric system within the constraints of processing, computing and power of the body sensor nodes
- Random: difficult to guess
- Collectable: easily measured and collected
- Universal: possessed by most patients
- Distinctive: sufficiently different in any two patients

G. Elliptic Curve Cryptography

Elliptic curve cryptography (ECC) presents itself as a viable option for public key cryptography in wireless sensor networks. The main reason for this is its small key size and compact signatures and its comparatively fast computation. Even though ECC has been successfully implemented in several variations it is still not a top choice for WBAN. This is mainly because of its energy requirements which are still significantly higher than symmetric systems. Because of this, many have proposed that ECC be implemented only for infrequent and security-sensitive operations such as key establishment during the initial setup of the network or code updates.

VII. FUTURE SCOPE AND CONCLUSION

Although wireless technology in the field of healthcare and medical applications is still nascent Wireless Body Area Network (WBAN) holds the promise to become a key infrastructure element in remotely supervised, home-based patient rehabilitation. As it has the potential to provide better and less expensive healthcare services and provides much benefit to patients, health care staffs, and the society. Already commercial products are being developed by several companies to solve wide range of health care problems. WBAN provides a continuous monitoring of the patient health it will improve the quality of life as it will allow patients to engage in normal activities of daily life, rather than staying at home or close to specialized medical services like hospital clinics etc. Some of the future applications of WBAN include Context-Sensitive Medicine, Patient Homecare and a Pre hospital Mobile Database for Emergency Medical Services.

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