Wearable Sensors for Remote Healthcare Monitoring System

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***Abstract*— In Today's tautness life people are facing multiple physical, physiological, psychological problems. They have no time to visit doctors again and again. Sometimes there is a situation when a patient requires treatment on the spot. To solve these problems we require a technique which collects all the data about people's disease in spaces ranging from personal to urban. Wireless sensor network (WSN) technologies are considered one of the key research areas in computer science and the healthcare application industries for improving the quality of life. The purpose of this paper is to provide a snapshot of current developments and future direction of research on wearable and implantable body area network systems for continuous monitoring of patients. In this paper, medical sensors were used to collect physiological data from patients and transmit it to Intelligent Personal digital Assistant (IPDA). This paper explains the important role of body sensor networks in medicine to minimize the need for caregivers and help the chronically ill and elderly people live an independent life, besides providing people with quality care. Although offering significant benefits, the field of wearable and implantable body sensor networks still faces major challenges and open research problems which are investigated and covered, along with some proposed solutions, in this paper.**

***Keywords*— Body area network, wireless network and Mobile Healthcare.**

I. INTRODUCTION

Due to advancement in technology a low-power networked systems and medical sensors are merged as wireless sensor networks (WSNs) in healthcare. These WSNs carry the promise of drastically improving and expanding the quality of care across a wide variety of settings and for different segments of the population. As healthcare costs are increasing and the world population is ageing, there has been a need to monitor a patient's health status while he is out of the hospital in his personal environment. To address this demand, a variety of system prototypes and commercial products have been produced in the course of recent years, which aim at providing real-time feedback information about one's health condition, either to the user himself or to a medical center or straight to a supervising Professional physician, while being able to alert the individual in case of possible imminent health threatening conditions. In addition to that, WSN constitute a new means to address the issues of managing and monitoring chronic diseases, elderly people, postoperative rehabilitation patients, and persons with special disabilities. But at the same time, meeting the potential of WSNs in healthcare requires addressing a multitude of technical challenges which are as follows: 1) it is possible to achieve highly reliable data delivery over multihop wireless networks deployed in clinical environments.[1][2]; 2) systems that overcome energy and bandwidth limitations [3]; 3) an analysis of privacy and security challenges and potential solutions in assisted living environments [4] and ; 4) technologies for dealing with the large-scale and inherent data quality. Human health monitoring [5-8] is emerging as a prominent application of the embedded sensor networks. A number of tiny wireless sensors are strategically placed on/in a patient's body, to create a WBAN [9]. A WBAN can monitor vital signs, providing real-time feedback to allow many patient diagnostics procedures using continuous monitoring of chronic conditions, or progress of recovery from an illness. Recent technological advances in wireless networking promise a new generation of wireless sensor networks suitable for those on-body/in-body networked systems.

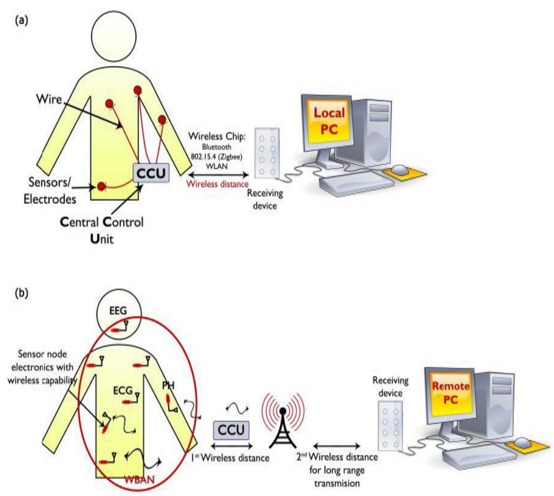

Figure 1. A typical WSN system for detecting and transmitting signals from a human body: **(a)** current application of healthcare sensor network and **(b)** future application of healthcare sensor network targeted by wireless body area network.

A typical wireless body area network is composed of a number of miniature, lightweight, low-power sensing devices, management electronics and wireless transceivers. As an indispensible part of the system, the power supply for these components should be small-sized, lightweight, environmentally-friendly and long lasting as well.

Unlike conventional WSNs, WBANs consists of smaller, less nodes and less space covered and fewer opportunities for redundancy. Scalability can lead to inefficiencies when working with the two to ten nodes typical of a WBAN. Adding sensor and path redundancy for solving node failure and network congestion problems cannot be a viable mechanism for a BASN seeking to minimize form factor and resource usage. WBANs also have a distinctly hierarchical nature. They capture large amount of data constantly and naturalistically that microprocessors should process to extract the needed information. Data processing must be hierarchical to exploit the asymmetry of resources, to maintain system efficiency, and ensure the availability of data, if necessary [10].

3. System Architecture of BAN

This section describes the system architecture of the proposed wearable sensors for remote healthcare monitoring system. The system is composed of three tiers as shown in **Figure 2** below.

The system composed of:

1) Wireless Body Area Network (WBAN);
2) Personal Server (PPS) using IPDA;
3) Medical Server for Healthcare Monitoring (MSHM).

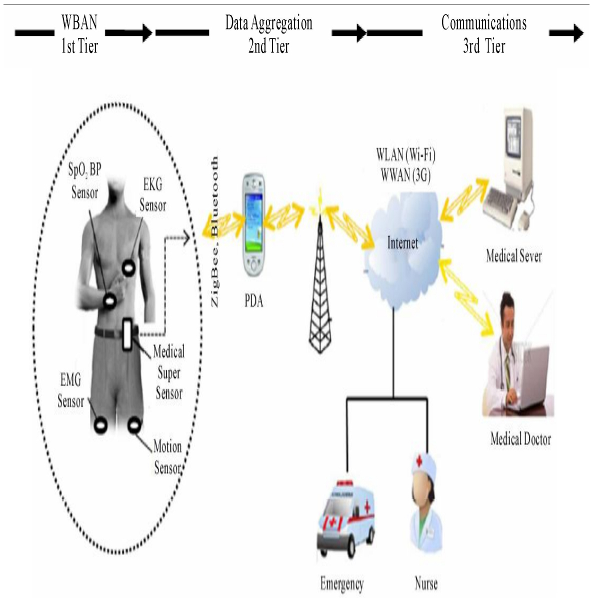

Figure 3 Architecture of wearable sensors for remote healthcare monitoring system

3.1. First Tier

The core of this system is the user called the patient. Wearable sensors are attacked to the patient body forming wireless body area network (WBAN) to monitor changes in patient's vital signs closely and provide real time feedback to help maintain an optimal health status. The medical sensors typically consist of five main components:

1) **Sensor:** it is a sensing chip to sense physiological data from the patient's body.

2) **Microcontroller:** it is used to perform local data processing such as data compression and it also controls the functionality of other components in the sensor node.

3) **Memory:** it is used to store sensed data temporally.

4) **Radio Transceiver:** it is responsible for communication between nodes and to send/receive sensed physiological data wirelessly.

5) **Power supply:** the sensor nodes are powered by batteries with a lifetime of several months [11].

Sensor nodes can sense, sample, and process one or more physiological signals. For example, an electro- cardiograph (EKG) sensor can be used for monitoring heart activity, a blood pressure sensor can be used for monitoring blood pressure, a breathing sensor for monitoring respiration, an electro-myogram (EMG) sensor for monitoring muscle activity, and an electroenphalogram (EEG) sensor for monitoring brain electrical arrive for each sensor.

In our design, a sophisticated sensor is integrated into the WBAN called Medical Super Sensor (MSS). This sensor has more memory, processing and communication capabilities than other sensor nodes .MSS uses a radio frequency to communicate with other body sensors and ZigBee is used as a communication protocol to communicate with the Personal Server.

Medical Super-Sensor (MSS) unobtrusively samples, collects multiple sensed vital signs by the body sensors, filtering out all redundant data thereby reducing large volume of data transmitted by BSNs, store them temporarily, process and transfer the relevant patient's data to a personal server through wireless personal implemented using ZigBee/IEEE 802.15.4. This improves overall bandwidth utilization as well as reducing power consumption of the BSs because each nodes does not need to transmit sensed data to the IPDA but to the cool-lector which is MSS and it is closer to the BSs than IP-DA and extending battery life of each sensor node.

3.2. Second Tier

Personal Server

The personal server interfaces the WBAN nodes through a communication protocol using ZigBee. It is implemented on an Intelligent Personal Digital Assistant (IPDA). It holds patient authentication information and is configured with the medical server IP address in order to interface the medical services. It collects physiological vital signals from WBAN, processes them, and prioritizes the transmission of critical data when there is sudden clinical change in the current patient condition and data content for example changes in cardiovascular signals, temperature, oxygen saturation, and forward it to the medical server.

Moreover, the IPDA has the capability to perform the task of analyzing the physiological data intelligently and do a local reasoning to determine user's health status based on data received from MSS and provide feedback through a user-friendly and interactive graphical user interface. 3G communications is used to connect personal server and third tier together but other long range communications protocols can also be used like GPRS, WWAN.

In order for IPDA to improve the overall quality of service for data transmission, in terms of latency, band-width and power consumption a differentiated service based on two schemes are presented. They are Priority Scheduling and Data

Compression. This method reduces energy consumed by the IPDA during transmission since only the critical vital signs will transmit first while less critical signs are stored and transmit later.

IPDA is inactive mode when it has no data to receive from MSS or send to the medical server in order to save energy but wake up immediately from inactive to active mode to receive transmitted data and store it. It prioritizes all the received physiological data and send to the medical server based on the priority order so that the medical staff will be adequately prepared before the patient gets to them or send ambulance immediately to pick the patient so as to save his/her life.

3.3 Medical Server for Healthcare Monitoring (MSHM).

The third tier is called Medical Server for Healthcare Monitoring (MSHM). It receives data from the personal server, is the backbone of the entire architecture. It is situated at medical centers where medical services are provided. It is intelligent because it is capable of learning patient specific thresholds and learns from previous treatment records of a patient [12]. MSHM keeps electronic medical records (EMRs) of registered patients, which are accessible by different medical staff, including general practitioners, specialists and doctors from their offices in the hospital over the internet. The present state of the patient can be observed by the medical staff. MSHM is responsible for user authentication, accepting data from personal server, format and insert the received data into corresponding EMRs, analyze the data patterns.

The patient's physician can access the data and its patterns from his/her office via the intranet/internet and examine it to ensure the patient is within expected health metrics. If the received data is out of range (*i.e.* deviation from threshold) or recognize serious health anomalies condition, medical staff in the emergency unit can be notified to take necessary actions. However, if the patient is in the remote area, the specialist doctor will 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 remote hospital via the internet. The MSHM also provides feedback instructions to the patient, such as physician's prescribed exercises.

In this paper, the current state in research and development of wearable low-cost unobtrusive systems for health-monitoring is reviewed by summarizing and comparing the attributes of the most promising current achievements of several worldwide projects and commercial products. Section II presents the most important and widely employed biosensor technologies along with the corresponding measured biosignals.

II. PHYSIOLOGICAL SIGNALS AND BIOSENSORS

This section provides a list of several sensing technologies as depicted in Table I, which can be integrated as part of a wearable health-monitoring system, along with their corresponding measured physiological signals. The measurement of these vital biosignals and their subsequent processing for feature extraction, leads to a collection of real-time gathered physiological parameters, which can give an overall estimation of the user's health condition at any given time.

Type of Sensor	*Description of measured data*
Skin/Chest Electrode	*Electrical Activity of heart*
Arm-cuff based Monitor	*Blood circulation in arteries*
Piezoelectric Sensor	*Breathing rate*
Pulse Oximeter	*Amount of oxygen in blood*
Skin electrodes	*Frequency of cardiac cycle*
Phonocardiograph	*Stethoscope*
Galvanic Skin responses	*Activity of sweat glands*
Strip base glucose meter	*Amount of Glucose in blood*

4. BAN Applications to Healthcare Promotion

Current healthcare applications of wireless sensor networks target heart problems [13,15,16], asthma[14,17,18], emergency response [19], stress monitoring [20]. The integration of existing specialized medical technology with pervasive wireless networks will be seen in the near future [21]. Medical applications benefit from wireless sensor networks in many ways. The recent advances in miniaturization of smart biosensors will open up new opportunities for continuous monitoring of patients. Nonintrusive, tiny wearable sensors will allow collection of vast amounts of data automatically, reducing the cost and inconvenience of regular visits to the physician. Thus, many more researchers may be enrolled, benefiting all research peers [22].

4.1 Cardiovascular diseases

Cardiovascular disease refers to various medical conditions that affect the heart and blood vessels. The conditions include heart attack, heart failure, stroke, coronary artery disease. This disease is the leading cause of mortality in the developed world [34,35].

World Heart Organization [36] stated that heart disease accounts for about 17 million (about 30%) deaths annually throughout the world and 80 percent of all deaths in China are caused by chronic disease [37] About one-half of those who die do so within 1 hour of the start of symptoms and before reaching the hospital.

A WBAN is a key technology that provides real-time monitoring of cardiovascular patients by continuously sense, process, and transmit physiological data from central control unit to the medical server through personal server, which the physician can make use of the information to treat the patients. Also promoting timely intervention of health care structure as and when required.

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4.2 Cancer Detection

National Centre for Health Statistics in their annual report stated that about 9 million cancer patients were diagnosed in 1999 and the number is increasing every year [23]. Cancer is now one of the biggest threats to the human life. A WBAN with a set of miniaturized sensors can be used to differentiate between different types of cells and

identifying cancerous cells, enabling physicians to diagnose tumors without biopsy.

4.3 Alzheimer, depression, and elderly people monitoring

According to the U.S. Bureau of the Census, the number of adults age 65 to 84 is expected to be doubled from 35 million to nearly 70 million by 2025. This trend is global, so the worldwide population over age 65 is expected to more than double from 357 million in 1990 to 761 million in 2025. In addition, a recent study found that almost one third of U.S. adults, most of whom held full-time jobs, were serving as informal caregivers mostly to an elderly parent. Wireless sensor network can help homebound and elderly people who often feel lonely and depressed by detecting any abnormal situation and alerting neighbors, family or the nearest hospital [24].

4.4 Glucose Level Monitoring

The US national institute of health (NIH) reported 15.7 million people had the emerging disease diabetes in 1999 in the US. Diabetes can yield other complicated diseases like heart disease, stroke, high blood pressure, blindness, kidney disease, and amputations. A biosensor implanted in the patient could provide a more consistent, accurate, and less invasive method by monitoring glucose levels, transmit the results to a wireless PDA or a fixed terminal, and by injecting insulin automatically when a threshold glucose level is reached [25].

4.5 Asthma

Millions of patients are suffering from asthma in the world, a WBAN can help these patients by monitoring allergic agents in the air and providing real-time feed-back to the physician and/or to the patient himself. A portable Global Positioning System (GPS) device was developed by Chu *et al.* [14] that continuously consult a remote server by sensing user's reports to decide whether current ambient air quality will threaten user's health. The server also collects real-time data from the network of national air quality monitoring stations. If it finds anything allergic to the patient, an alarm to the patient and/or physician will be triggered.

4.6 Epileptic Seizures Strike Early Warning

Strokes affect 700,000 people each year in the US and about 275,000 die from stroke each year [26]. Wearable sensor system has the ability to monitor home bounded people by measuring motor behavior at home for longer time and can be used to predict clinical scores.

Researchers at the University of Chicago Medical Center are developing a device called "Mobi"**,** using TMSI technology that could change the lives of patients who suffer from seizures. They are trying to develop an early warning algorithm for epilepsy [27]. The portable unit "Mobi" is designed to detect abnormal brain activity that happens before a seizure. When the signs of electrical trouble are picked up the device will transmit a warning to a receiver and the patient could then take steps to set down or tell someone. But finding an algorithm that would detect for a particular patient when the seizure is about to start is still an issue.

4.7 Diabetes

World Health Organization (WHO) reported that more that 220 million people worldwide have diabetes and 1.1 million people died from diabetes in 2005. Following are some of the complications that occur as a result of diabetes: amputations, blindness, kidney disease, stroke, high blood pressure, heart disease [28] Treatment includes blood pressure control, exercise, insulin injections. A WBAN can be used in a more effective way to treat diabetes, by providing a more consistent, less invasive and accurate method for monitoring glucose levels in the body.[29]

4.8 Artificial Retina

Optoelectronic Retina Prosthesis (ORP) chips can be implanted into the back of human eye, which assist blinds and/or patients with low vision to see normally.

IV Challenges Associated with BAN

BAN technology is still emerging and there are a lot of problems left to solve. Setting aside ethical issues like privacy, there are still plenty of technical challenges that we must overcome before BAN will become an effective solution. The BAN draft submissions have defined solutions for a lot of the basic wireless network protocols, but there is still a large amount of research that must be done to effectively propagate a signal in and around the human body. The last challenge BAN technology faces is actually a problem of Human-Computer Interaction (HCI) and how to make the technology usable.

1) **Signal & Path Performance:** As one might expect, the signal and path loss inside the human body is drastically different than the rules in plain space. That said the rules governing signal and path loss remain the same. Researchers have been able to model signal loss throughout the human body, however the more interesting research involves using the human body as a transmission medium for electrical signals. Marc Wegmueller et al. have attempted to model the conductivity and permittivity of signals sent from one area of the body to another. It is worth noting that in the frequency range of 10 kHz to 1MHz, for every 5 cm between the transmitter and receiver there is an increase in attenuation by 6 to 9 dB. Other factors lowered or raised these constants, such as the geometry of the path, the amount of fat, and the presence of joints.[31]

2) **Usability:** Given the close proximity of users to the BAN technology, the demands on usability are exceptionally high. Zheng et al. noted a usability problem with previous systems such as Lifeguard and AMON, the technology placed artificial restrictions on the user, which made adoption more difficult. Zheng's group decided to use advances in textile manufacturing to sensing wearable shirts that would actively monitor the wearer. Interestingly enough, Zheng's group also found a usability fault in the EPI-MEDICS design, as the system would record ECG data and raise alarms as required, but it would only do so when requested by the patient. Zheng's group classified this as a usability flaw, as the usefulness of emergency detection sensors is in their detection of emergencies that are not planned.[30]

Communication Challenges: The prime factor in medical application is to provide a mechanism for secure and reliable communication among the various groups of sensors, handheld devices & mobile. Each device follows different standards depending on their company's standards. So there comes a great challenge how well they are going to be integrated. Since these devices work with short range radio transmission, a method needs to be devised for making sensor networks utilise the available GSM/CDMA infrastructure to enable communication for large distance.

Computational Challenge: Sensor networks are self organizing and operate with low power[32] and very little computational capacity. There is a limit on the type and complexity of application data that these devices can operate on. The system must allow physicians, nurses, and others to assign access rights to patient data quickly and determine their data dynamically when a patient is transferred to another unit or hospital. Existing authentication systems are extremely rigid in this regard.

Programming Challenge: Also one should accept that Wireless devices are slower than wired because of traffic congestion and hence increases the challenge to create the devices that could reach to better performance. This creates a big challenge for developers in programming and designing a secure sensor network. Ensuring patients information security can be a major issue when deploying these applications. Privacy of user data over wireless channels can be another major issue. Wireless network based medical devices can be very limited in terms of power availability and processing strength. Thus ensuring privacy without using complex encryption algorithms can be a big issue for developers of medical devices.[33]

V. FUTURE SCOPE

Although wireless technology in the field of medical applications is still relatively new, commercial products are being developed by several companies to solve wide ranging problems. In some cases these new applications are design purely social health benefits i.e. reducing interference to daily life when dealing with long term patient care. Some of the future applications:

- Patient Homecare
- Context-Sensitive Medicine
- iRevive (A Prehospital Mobile Database for Emergency Medical Services).

SUMMARY

Wireless networks for Medical Applications are becoming a hot topic in the industry. In this deep study paper, we focused our discussion on the benefits of using wireless networks for medical applications. We have discussed about how these new Wireless technologies can be utilized in potential manner to get benefits for the human well being. Thus these technologies help us to design less intrusive Wireless sensor devices, which help us in ensuring human life. After having a study about the wireless networks, we acquired good knowledge about it. We are planning to implement the ideas whatever we gained from this deep study to contribute to the medical application that could help the whole mankind.

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