TELKOMNIKA, Vol.15, No.3, September 2017, pp. 1088~1095
ISSN: 1693-6930, accredited **A** by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v15i3.5793

Wireless Body Area Networks for Healthcare Applications: An Overview

Muhammad Anwar*[1], Abdul Hanan Abdullah[2], Kashif Naseer Qureshi[3], Abdul Hakeem Majid[4]
[1,2,4]Faculty of Computing, Universiti Teknologi Malaysia, Skudai, Johor Bahru, Malaysia
[3]Faculty of Computer Science, Bahria University, Islamabad, Pakistan
*Corresponding Author e-mail: anwer.mirza@gmail.com

Abstract

Healthcare systems have been facing various new challenges due to increasing and rising aging population in healthcare. Advance information and communication technologies have introduced Wireless Body Area Networks (WBANs) for healthcare systems. WBANs provide different monitoring services in healthcare sector for monitoring their patients with more convenience. WBANs are economical solutions and non-invasive technology for healthcare applications. This review paper provides a comprehensive review on WBANs applications, services and recent challenges.

Keywords: *WBANs, Healthcare applications, services, Telemedicine*

1. Introduction

Recently, the main challenges in healthcare sector are increasing the aging population decreasing healthcare facilities. According to the US Bureau of Census, it is predicted and expected that the number of old people in the world will be double. This population was 375 million in 1990 and will be double around 761 million in 2025 [1]. Usually, the old people have suffered with various chronic diseases and need continues medical care. Most of the patients are staying in hospitals or need continues supervision from medical professionals, otherwise they lives may be at risk [2].

Millions of people have died from chronic or fatal diseases every year. The most common reasons of such fatal diseases are lack of diseases diagnostic services in time. The authors in [3] revealed that, the most of the diseases can be controlled if they are identified in their early stages. So there is a pressing need of proactive, affordable and fast healthcare systems for continuous health monitoring and early detection of the diseases. With the advancement of new wireless technologies, Wireless Body Area Networks (WBANs) was introduced by Latré, et al [4]. These networks contain intelligent and small bio-medical sensors which are implanted in patient body or on patient body. These sensor nodes process the information and further send to a medical server where this information is stored and analyzed by doctors or medical specialists. Different types of monitoring applications in WBANs provide easy and cost effective solutions in healthcare.

These advance systems facilitate the patients with physical mobility support without stay long in hospitals. In WBANs, the system has different monitoring sensors nodes such as sensors and actuators. The sensor nodes are used to measure the certain body parameters whereas the actuators act on received data from other sensor nodes. In addition, the personal devices act as control unit to collect data from sensor nodes and transmit to the medical server using wireless link [5]. Figure 1 shows the biometric sensor nodes example.

The rest of the paper is organized as follows: Section 2 presents the key features and applications of WBANs for healthcare systems. Section 3 provides WBANs wireless communication standards. Section 4 presents WBANs architecture. Section 5 points out the recent issue & challenges in WBANs. In last, paper concludes with future direction.

Received April 2, 2017; Revised June 12, 2017; Accepted June 30, 2017

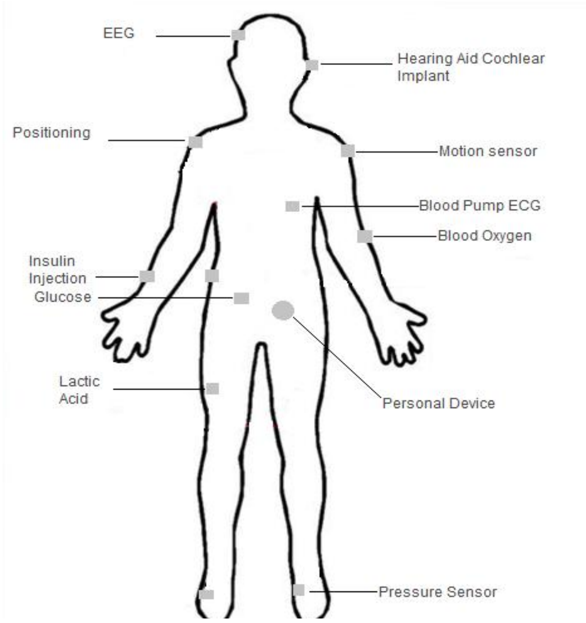

Figure 1. Biometric sensor nodes in WBANs

2. Applications of WBANs

WBANs provide a wide range of monitoring applications in different fields such as ubiquitous healthcare, emergency, military, sports, interactive gaming and many others [6]. In the section, we discuss the WBANs applications for healthcare field.

2.1. Medical Applications

WBANs provide continues health monitoring of patients and manage the necessary medication during their stay at home or elsewhere [7]. The in body sensor nodes are monitoring patient inside organs functions such as pacemakers and implantable cardiac defibrillators, restoration of limb movement and control of bladder function. On-body sensor nodes are used in medical applications to monitoring the body blood pressure, heart rate, temperature and respiration. Some of the WBANs applications are discussed in following sub-sections.

2.1.1. Cardiovascular Application

This application is used to monitor cardiovascular disease which is one of the primary reason of death. According to [8], more than twenty million people have effected from this disease in the world. WBANs can be used to prevent enormous deaths by continuous monitoring of patient for their health. The healthcare service providers can prepare patient treatment in advance by any abnormal information from sensor nodes about heart rate or irregular heart functions.

2.1.2. Cancer Detection Application

Nowadays cancer is one of the biggest threats for the human life. It effects millions of people and number of effected people are increasing every year [9]. A set of small sensor nodes have capabilities to detect the nitric oxide which usually produced by cancer cells. Sensor nodes can be placed in the patient body infected locations in the patient body. This allows medical professionals to detect cancer tumors without any biopsy.

2.1.3. Monitoring Blood Glucose Application

Diabetes is one of the serious chronic diseases in all over the world. According to the World Health Organization, diabetes has been gradually increasing over the years. More than 400 million adults are suffering from diabetes in the world. If this disease is not treated properly, it can causes some other serious complicated diseases in body like blindness, stroke, kidney disease, heart disease and high blood pressure [10]. WBANs can provide effective treatment to diabetes patients by providing continuous and accurate monitoring glucose level in blood.

Currently, the typical way to measure blood glucose level is to prick the finger and place the blood drop on the test strip. This method can damage the tissues by constant pricking over the years. Wireless biomedical sensors can be implanted in the patient body and less invasive to monitor the body glucose level several times in a day. Through WBAN sensors, doctors also inject insulin in patient automatically using actuator node whenever a glucose level is reached at certain threshold [11].

2.1.4. Asthma Detection Application

WBANs applications can help millions of asthma patients by detecting allergic agents in the environment and provide continues feedback to the physician as well as patient [12].

2.1.5. Stress Monitoring Application

Stress is a foremost cause of illness and different diseases. Chronic stress leads to produce psychological issues such as high depression and anxiety. It can also cause of high coronary heart disease, morbidity and mortality. WBANs can provide real time monitoring and stress in individuals and help their physicians for proper treatment [13].

2.1.6. Artificial Retina Application

Retina prosthesis chips can be implanted in the human eye, which will help patients who are suffering from no vision or limited vision and able to see at adequate level. In the Smart Sensors and Integrated Microsystems (SSIM) project by Wayne State University and Kresge Eye Institute, a retina test system developed which consist of integrated circuit and array of sensors [11, 14].

2.1.7. General Health Monitoring Applications

WBANs have also been proposed for general health monitoring. These types of applications help those patients which are free from the hospital however their health status is continuously monitored by these applications.

2.2. Non-Medical Applications

WBANs also offer other non-medical applications such as for public safety, monitoring battlefield activities, gaming and entertainment applications.

3. WBANs Standards

With the growing popularity and wide variety of WBANs applications in medical and Information and Communication Technologies (ICTs), this technology needs more new standards and communication models. One of the most successful standard in WBANs is IEEE 802.In addition, for the standardization of WBANs, IEEE established a Task Group in 2007. The aim of this group is to establishing a communication standard for low power WBANs nodes to support various medical and non-medical applications. This group was released IEEE 802.15.6 in February 2012 as the first international WBANs Standard. This standard defines Media Access Control (MAC) Layers and several physical layers standards such as Narrowband (NB), Ultra-wideband (UWB), and Human Body Communications (HBC) as shows in Figure 2. The selection of PHY layer or frequency band depends on the application type which is also addressed by the communication standard [12].

In most of the countries, the available frequencies for WBANs are regulated by their relevant authorities. Table 1 shows the summery of available frequency bands for WBANs [15] adopted by different counties. Medical Implant Communications Services (MICSs) band is a licensed band which was reserved for implant communications in WBANs with 402-405MHz frequency range in many countries.

Wireless Medical Telemetry Services (WMTSs) is another licensed band reserved for medical telemetry systems. Both MICS and WMTS bands do not have ability to support high data rate applications. Industrial, Scientific, and Medical (ISM) and Ultra-wideband (UWB) bands support high data rate applications and are available globally. However, there is a possibility of interference as many wireless devices operates in the 2.4GHz band [13].

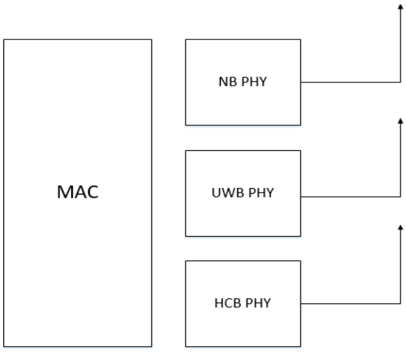

Figure 2. IEEE 802.15.6 MAC and PHY Layers Standards

Table 1. Frequency bands for WBANs

Frequency band	Description
5 to 50 MHz	Human Body Communication (HBC) Band
402 to 405 MHz	Medical Implant Communications Service (MICS) band, Narrowband (NB)
420to 450 MHz	WMTS Band (used in Japan), Narrowband (NB)
605 to 614 MHz	WMS Band (used in USA), Narrowband (NB)
1395 to 1400 MHZ	
863 to 870 MHz	WMTS Band (used in Europe), Narrowband (NB)
902 to 928 MHz	ISM Band (used in New Zealand, Australia, North America), Narrowband (NB)
950 to 956 MHz	Used in Japan) Narrowband (NB)
2360 to 2400 MHz	Narrowband (NB)
2400 to 2450 MHz	ISM Band (used in Worldwide), Narrowband (NB)
3100 to 1600 MHz	UWB Band

3.1. MAC Layer Specifications for WBANs

According to the IEEE802.15.6 standard [14], the WBANs consist of a single hub and several sensor nodes. The sensor nodes are connected through one or two hopped star WBANs. A hub controls the entire operation of each WBANs. In a two hopped start WBANs, data frames are exchanged between a node and the hub through a relay capable node.

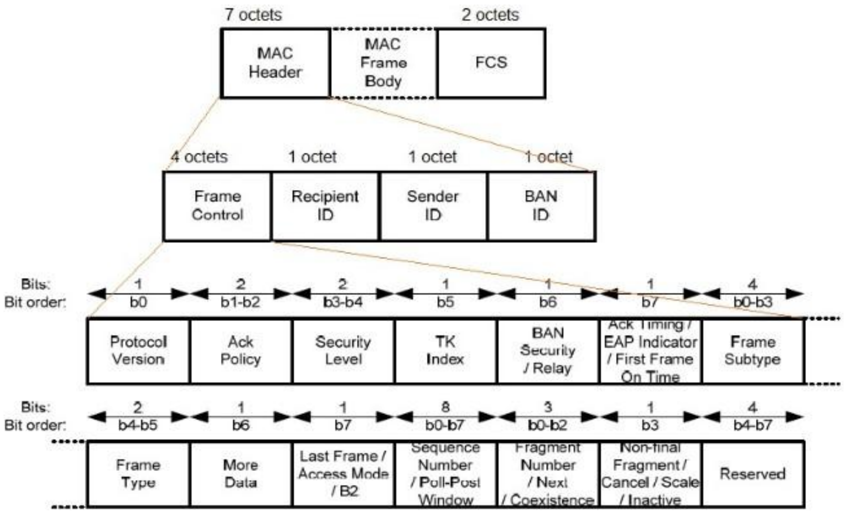

Figure 3. WBAN MAC format

- Beacon Mode with Super frame Boundaries
- Non-beacon Mode with Super frame Boundaries
- Non-beacon Mode without Super frame Boundaries

As per IEEE802.15.6 standard, the channel is partitioned into super frames or beacon periods of same length. Each super frame contains number of allocations slots which are used for data transmission. The boundaries of the beacon period and allocation slots are selected by the hub.

The hub may also shift or rotate the offsets of the beacon period. Generally, the beacons are transmitted in each beacon period except in inactive super frames or unless prohibited by regulations such as in MICS band. The IEEE standard 802.15.6 network operates in one of the following modes.

3.2. PHY Layer Specifications for WBANs

IEEE 802.15.6 standard is classified for physical (PHY) layer and divided into three types: Narrowband (NB), Ultra-wideband (UWB), and Human Body Communications (HBCs). The UWB and HBC are mandatory for PHYs layer whereas NB PHY is optional [16]. The functions of physical layers are activation & deactivation of radio transceiver of the nodes, clear channel assessment and data transmission & reception.

3.2.1. Narrowband PHY Specifications

NB PHY transforms physical layer service data unit (PSDU) into a Physical layer Protocol Data Unit (PPDU) by appending physical layer preamble and physical layer header with PSDU. The physical layer preamble and physical layer header support for demodulating, decoding and deliver of PSDU at receiver end.

PPDU format consists of three main components which are listed by transmission order are (1) Physical Layer Convergence Protocol (PLCP) preamble (2) PLCP Header (3) PSDU. Whereas, preamble are used to help the receiver for time synchronization and carrier-offset recovery. The second main component of PPDU is PLCP header at the receiver end, the decoding of PSDU conveys the necessary information about the PHY layer parameters. Data rates of the available frequency band are used to transmitting the PSDU. It consists MAC header, frame body and Frame Check Sequence (FCS).

3.2.2. Ultra-wideband PHY Specifications

Ultra-Wide Band (UWB) PHY layer provides opportunities for large scope implementation in WBANs for high performance, ultra-low power operations and low complexity. The signal power level of UWB lies in MICS band. Therefore this level provides harmless effect to the human body by providing safe power level to other low power devices as well as to human body. The UWB PHY layer uses Physical Layer Convergence Protocol (PLCP) to provide data interface to MAC layer. UWB PHY provides the following functionalities:

1. Activation and deactivation of the radio transceivers.
2. The PLCP creates Physical Layer Protocol Data Unit (PPDU) which consists of Synchronization Header (SHR), Physical layer Header (PHR), and PSDU. To transmit on the wireless medium, the PPDU bits are converted into RF signals.
3. To verify the activity in the wireless medium, the UWB PHY may also provide the Clear Channel Assessment (CCA) indication to MAC.

3.2.3. Human Body Communication PHY Specifications

Human Body Communications (HBC) physical layer uses the Electric Field Communication (EFC) technology. It works at 21 MHz centered frequency. The HBC packet consists of PLCP Preamble, Start Frame Delimiter (SFD), PLCP Header, and PHY Payload (PSDU) whereas the MAC Header, MAC Frame Body, and Frame Check Sequence (FCS) constitute the PHY Payload. Before transmission of data, it is spreading in frequency domain by frequency selective spread codes and centered frequency for transmission is selected. This method is known as Frequency Selective Digital Transmission (FSDT) scheme [17]. The HBC packet structure shows in Figure 4.

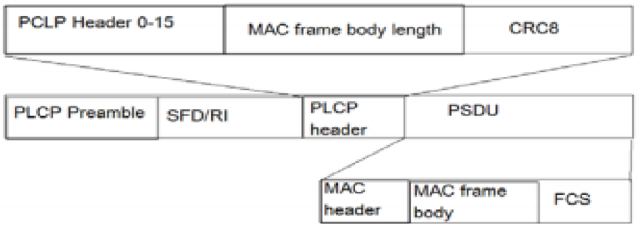

Figure 4. Packet structure of HBC PHY

4. WBANs System Architecture

WBANs systems architecture is illustrated in Figure 5 which consists of several wireless devices and network components.

Sensors Nodes: Sensor nodes measure the vital parameters of human body and process the collected data and transmitted to the control unit. Some types of these sensor nodes are Heartbeat, Temperature, Humidity, DNA Sensor, Transmission Plasmon Biosensor, Thermistor, Magnetic Biosensors, Spirometer, Blood Glucose, Pulse Oximetry, Motion, Electrocardiogram (ECG), EEG, and EMG. The design of sensor nodes of WBANs is critical and should fulfill the main requirements such as wear ability, reliability, security and interoperability. A sensor node consists of sensor hardware, processor, memory, power unit and a transceiver.

Actuator Nodes: This device act according to the data received from the sensor node or through the interaction with user. It consists of actuator hardware to administer medicine, processor, memory, power unit and transmitter/transceiver.

Personal device/Control Unit: A device that collects the information from sensors and actuators and sent to the medical server over internet. This device is also called a Body Control Unit (BCU).

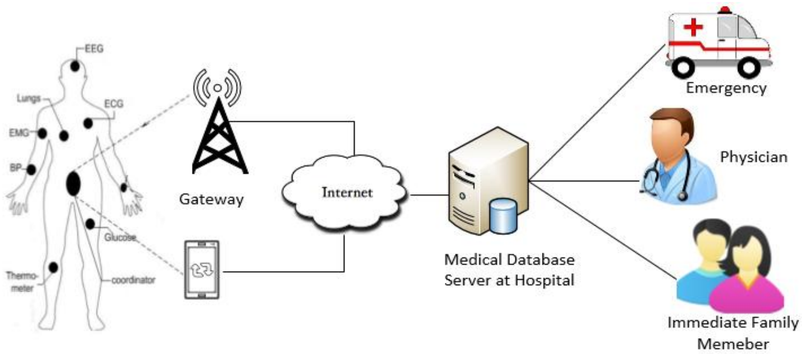

Figure 5. System Architecture of WBANs

The sensor nodes are attached on the body which are always activated and continuously send their data to Network Coordinator. They consume high energy but it reduces the operational time.

This configuration causes high energy consumption in all medical sensors and reduces their operational time. WBANs architecture presented in Figure 1, it showed several key components. Different types of medical sensors can be used for monitoring various vital parameters. Figure 2, represents the other form of WBANs in which data from the multiple nodes transmitted through the internet to multiple clients.

5. Existing Challenges

In this section, we describe the current issues and challenges of WBANs. The open research issues related to the growing technology of WBANs are like energy efficiency of sensors, architecture and protocol design, interoperability, security & privacy, and quality of service.

Energy efficiency of the WBANs sensor nodes are the main critical issue in ubiquitous mobile health monitoring systems. The rechargeable batteries may be one of the solutions but recharging the batteries of several sensor nodes may be a burden for the patients. Especially the elderly patients may forget to get recharge on time. So the auto rechargeable systems may be applied to overcome this issue. There is a need of studying energy scavenging techniques [18]. The researchers from biochemistry side are trying to apply the techniques to optimize the energy of the battery by some phosphates presents in a human body. The computer science researcher has applied the multiple approaches during the data transmission at RF radio frequency bandwidth. They applied these techniques for the better data transmission including CDMA, FDMA, CSMA and TDMA, the best one found among these are TDMA.

Security is one of the concerned topics in WBANs network to protect privacy of medical data. Security of the WBANs depends upon data confidentiality, data authentications, and secures localization secure management. These are the main factors to secure any wireless network.There are variety of security attacks like Denial of Service Attacks (DOS), privacy violation and physical attacks. When applied on the network and different results have been answered.

Table 2. Layers and Attacks

Layers	Types of Attack	Suggested Solution
Physical layer	Jamming	Prevent from intruders and extruders
Link layer	Collision, Tampering	TDMA
Network layer	Misdirection	Side channel analysis
Transport	Authentication	Authentication certificate of the data

There are different best securities methods have been applied to secure the data. Welch Gong (WG) technique employs for the designed ubiquitous computing and produces good result for the security. Other modern public key cryptography techniques like lattice based cryptography, elliptic curve cryptography and quantum cryptography are also used for secure the network.

Architecture of the WBANs has its own importance and it is divided into three levels.

1. Level – 1 (Lowest level – contains intelligent sensors)
2. Level – 2 (Devices communicate with external low level devices)
3. Level – 3 (External servers which provide different tasks and services)

Server keeps the record for managing the data of the patients and provided when user demanded. Data management of sensor node is another issue. It reduces the usage of sensor node. At the same time, the data management and security assistance of the architecture is another main issue.

Quality of Service (QoS) is a major aspect in WBANs. The main concern of QoS is optimal utilization of resources over wireless networks and Internet. Unfortunately, this area did not get lot of interest from the researchers like other areas such as energy efficiency and security. There is limited work available in the area of QoS. The major QoS Challenges are resource limitations, Unpredictable traffic pattern, network instability, data redundancy and energy balance [19].

6. Conclusion

WBANs have been gained popularity due to its different monitoring applications and healthcare services. The modern health systems provide more convenient for the patients and medical centers. This paper reviewed this area in a broad manner, its standards and applications, architecture. In addition, this paper provides a platform to understand the WBANs for further research and highlighted its benefits and current research challenges. In future, we will discuss in depth overview to highlight the technical issues in the field of WBANs.

References

[1] SP Keehan, GA Cuckler, AM Sisko, AJ Madison, SD Smith, DA Stone, et al. National health expenditure projections, 2014–24: spending growth faster than recent trends. *Health Affairs.* 2015; 34: 1407-1417.

[2] K Awan, KN Qureshi, M Mehwish. Wireless Body Area Networks Routing Protocols: A Review. *Indonesian Journal of Electrical Engineering and Computer Science.* 2016; 4.

[3] S Movassaghi, M Abolhasan, J Lipman, D Smith, A Jamalipour. Wireless body area networks: A survey. *IEEE Communications Surveys & Tutorials.* 2014; 16: 1658-1686.

[4] B Latré, B Braem, I Moerman, C Blondia, P Demeester. A survey on wireless body area networks. *Wireless Networks.* 2011; 17: 1-18.

[5] F Ullah, AH Abdullah, MQ Jan, KN Qureshi. Patient data prioritization in the cross-layer designs of wireless body area network. *Journal of Computer Networks and Communications.* 2015; 2015: 5.

[6] KN Qureshi, AH Abdullah, RW Anwar. *The Evolution in Health Care with Information and communication Technologies.* in ELSEVIER, 2nd International Conference of Applied Information and Communications Technology. Oman. 2014.

[7] G Ragesh, K Baskaran. An overview of applications, standards and challenges in futuristic wireless body area networks. 2012.

[8] S Ullah, P Khan, N Ullah, S Saleem, H Higgins, KS Kwak. A review of wireless body area networks for medical applications. 2010.

[9] JV Frangioni. New technologies for human cancer imaging. *Journal of clinical oncology.* 2008; 26: 4012-4021.

[10] WH Organization. Global report on diabetes. 2016.

[11] L Schwiebert, SK Gupta, J Weinmann. *Research challenges in wireless networks of biomedical sensors.* In Proceedings of the 7th annual international conference on Mobile computing and networking. 2001: 151-165.

[12] D Oletic. Wireless sensor networks in monitoring of asthma. 2009.

[13] A Milenković, C Otto, E Jovanov. Wireless sensor networks for personal health monitoring: Issues and an implementation. *Computer communications.* 2006; 29: 2521-2533.

[14] N Xu. A survey of sensor network applications. *IEEE communications magazine.* 2002; 40: 102-114.

[15] S Ullah, M Mohaisen, MA Alnuem. A review of IEEE 802.15. 6 MAC, PHY, and security specifications. *International Journal of Distributed Sensor Networks.* 2013; 9: 950704.

[16] KS Kwak, S Ullah, N Ullah. *An overview of IEEE 802.15. 6 standard.* In Applied Sciences in Biomedical and Communication Technologies (ISABEL), 2010 3rd International Symposium on. 2010: 1-6.

[17] JH Kurunathan. Study and overview on WBAN under IEEE 802.15. 6. *U. Porto Journal of Engineering.* 2015; 1: 11-21.

[18] H Alemdar, C Ersoy. Wireless sensor networks for healthcare: A survey. *Computer Networks.* 2010; 54: 2688-2710.

[19] M Ameen, A Nessa, KS Kwak. *QoS issues with focus on wireless body area networks.* In *Convergence and Hybrid Information Technology, 2008. ICCIT'08. Third International Conference on.* 2008: 801-807.