Journal of Computer and Communications, 2017, 5, 53-64
http://www.scirp.org/journal/jcc
ISSN Online: 2327-5227
ISSN Print: 2327-5219

Wireless Body Area Network: An Overview and Various Applications

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How to cite this paper: Arefin, Md.T., Ali, M.H. and Haque, A.K.M.F. (2017) Wireless Body Area Network: An Overview and Various Applications. *Journal of Computer and Communications*, **5**, 53-64.
https://doi.org/10.4236/jcc.2017.57006

Received: March 21, 2017
Accepted: May 14, 2017
Published: May 17, 2017

Abstract

Over the past years a booming interest is comprehended in the field of wireless communication for the development of a monitoring system to observe human vital organs activities remotely. Wireless Body Area Network (WBAN) is such network that provides a continuous monitoring over or inside human body for a long period and can support transmission of real time traffic such as data, voice, video to observe the status of vital organs functionalities. In this paper an overview of WBAN technology and its requirements has been narrated. The aim of this paper was to offer a suitable and appropriate wireless technology for deploying WBAN. Several suitable short range wireless communication technologies that can be adopted in WBAN have also been discussed. Finally numerous applications in the field of medical and non-medical sectors using WBAN technology have been outlined.

Keywords

WBAN, WiFi, Bluetooth, ZigBee, Monitoring Sensors, WBAN Applications

1. Introduction

In modern technology wireless communication provides a lot of possibilities to be able to share its information to each other at anytime and anywhere. Intelligent mobile communication network and WLAN, WiFi are applied to various sectors such as education; health care service and industry in order to provide people a convenient way to communicate with each other. As the demand of ubiquitous network is increased, the devices for home, office and other information devices that can communicate wireless in short range have been getting more attention. The standard and technique development of ubiquitous network has rapidly put itself into the world market. Wireless Body Area Network (WBAN) is becoming a special application of such technique. WBAN differs

with other wireless sensor networks (WSN) with some significant points. First difference between a WBAN and WSN is mobility. In WBAN user can move with sensor nodes with same mobility pattern whereas WSN is generally used to be stationary. Energy consumption is much less in WBAN than other WSNs arrangement. In addition WBAN sensor devices are found cheaper than WSNs. For reliability, node complexity and density, WBAN nodes are however traditional. WSNs do not tackle specific requirements associated with the interaction between the network and the human body.

There are several wireless technologies such as Low power WiFi, Bluetooth, ZigBee and IEEE 802.15.6. In this paper we have discussed about the general architecture of WBAN, adopted technologies and its possible applications in different areas.

2. WBAN Architecture

WBAN is designed with special purpose sensor which can autonomously connect with various sensors and appliances, located inside and outside of a human body.

Figure 1 demonstrates a simple WBAN architecture where the architecture is divided into several sections. Here we have classified the network architecture into four sections. The first section is the WBAN part which consists of several numbers of sensor nodes. These nodes are cheap and low-power nodes with inertial and physiological sensors, strategically placed on the human body. All the sensors can be used for continuous monitoring of movement, vital parameters like heart rate, ECG, Blood pressure etc. and the surrounding environment. There are vast monitoring systems are being used already based on wired connections. Any wired connection in a monitoring system can be problematic and awkward worn by a person and could restrict his mobility. So, WBAN can be a very effective solution in this area especially in a healthcare system where a patient needs to be monitored continuously and requires mobility.

The next section is the coordination node where the entire sensor nodes will directly connected with a coordination node known as Central Control Unit (CCU). CCU takes the responsibility to collect information from the sensor nodes and to deliver to the next section. For monitoring human body activities

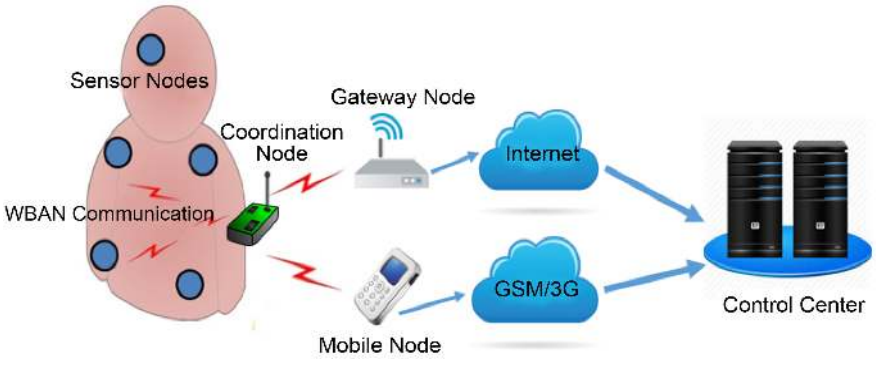

Figure 1. WBAN Architecture.

there is no such wireless technology is fixed for targeting WBAN. Most popular wireless technologies used for medical monitoring system are WLAN, WiFi, GSM, 3G, 4G,WPAN (Bluetooth, ZigBee) etc. [1]. Except Cellular network standard all of these technologies are commonly available for short distance communication. WMTS (Wireless Medical Telemetry Service) and Ultra-Wide Band [1] are another technology that could be used for body monitoring system as they operate in low transmission power.

The third section is the WBAN communication which will act as a gateway to transfer the information to the destination. A mobile node can be a gateway to a remote station to send Mobile Message to a cellular network using GSM/3G/4G. A router or a PC can be a remote node to communicate via email or other service using Ethernet which is shown in **Figure 2**.

The last section will be a control center consists of end node devices such as Mobile phone for message, PC for monitoring and email and server for storing the information in the database.

3. WBAN Requirements and Workflow

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads—the template will do that for you.

3.1. Requirements for Wireless Medical Sensors in WBAN

Wireless medical sensors should satisfy the following main requirements such as

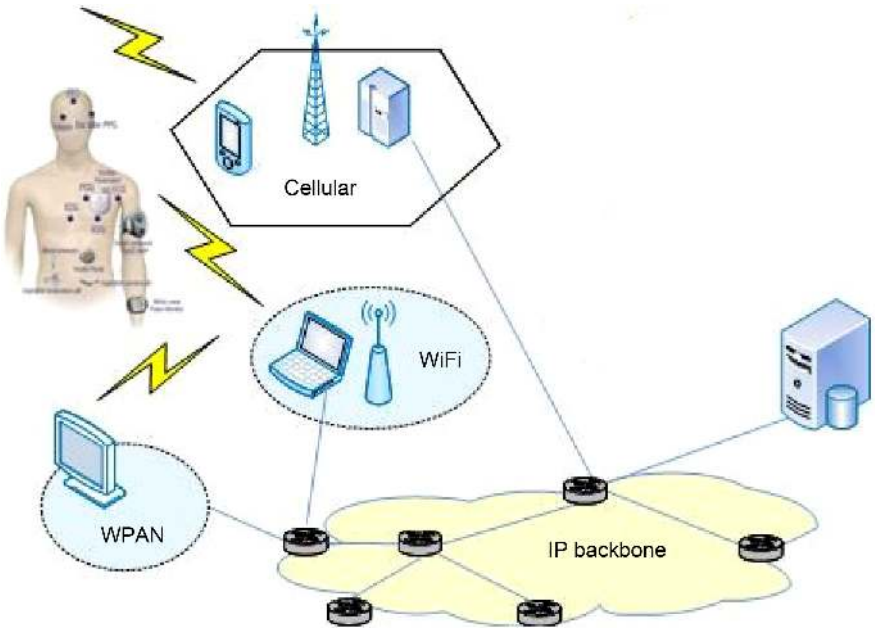

Figure 2. A Typical WBAN communication.

wearability, reliability, security, and interoperability [2]:

Wearibility: To achieve non-invasive and unobtrusive continuous monitoring Wearibility is a very important issue. These sensors must be lightweight and small. Size and weight of sensors are mainly determined by the size and weight of batteries [3]. But, a battery's capacity is directly proportional to its size.

Reliability: Reliable communication in WBANs is of paramount importance for any WBAN application. So the designer should target a reliable communication technique which will ensure uninterrupted communication and optimal throughput. A careful trade-off between communication and computation is very crucial for a reliable system design.

Security: Another important issue is the security of the network. All the wireless medical sensors must meet the requirements of privacy and should ensure data integrity and authentication.

Interoperability: Wireless medical sensors should allow users to easily build a robust WBAN. Standards governing that interaction of wireless medical sensors will help vendor competition and eventually lead to more accessible systems [4].

3.2. Monitoring Sensors

Wireless body area network is a system which can continuously monitor a person's activities. Based on the operating environments the monitoring sensors can be classified into two types.

- ❖ Wearable sensor devices worked on the human body surface.
- ❖ Implantable devices operated inside human body

Wearable sensor devices allow the individual to follow closely the changes in her or his functions and in the surrounding environment and provide feedback for maintaining optimal and instant status. For example ECG, EEG, Blood pressure sensor can be used to monitor a critical patient, GPS sensor can be used to locate an area and different types of sensor that can be used to measure the distance, temperature, movement etc.

To measure heath parameters, implantable sensors are planted in close contact with the skin, and sometimes even inside the human body. Implantable biosensors are an important class of biosensors based on their ability to continuously measure metabolite levels, without the need for person interference and regardless of the person's physiological state (sleep, rest, etc.) [5]. the implantable biosensors have great impact to diabetes and trauma care patients, as well as soldiers in action (military). **Figure 3** focuses on the sensor nodes with wireless capabilities.

3.3. Traffic Types

In a WBAN traffic can be divided into three categories such as [6]:

- ❖ Normal traffic
- ❖ Emergency traffic
- ❖ On-demand traffic

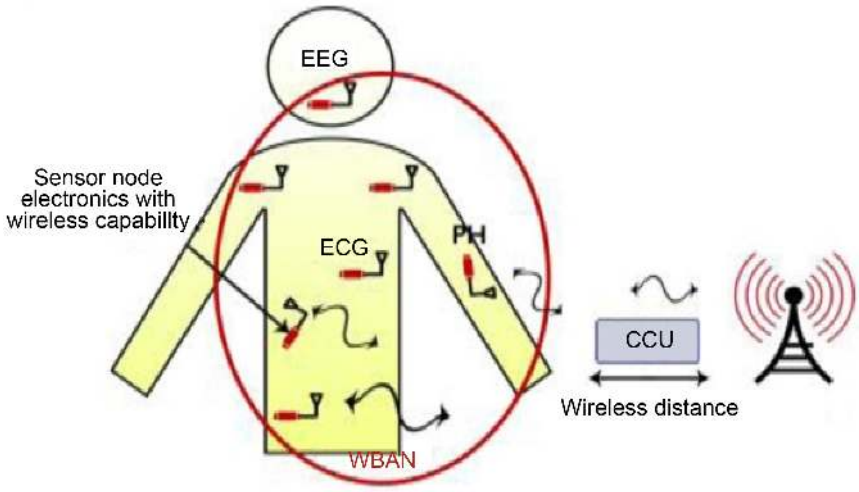

Figure 3. Sensor nodes in WBAN.

Normal traffic is the data traffic which is used to monitor the normal condition of a person without any criticality and on demand events. Emergency traffic is initiated by nodes when they exceed a predefined threshold or in any emergency situation. Such type of traffic is totally unpredictable.

On-demand traffic is initiated by the authorized personnel like doctor or consultant to acquire certain information for diagnostic purpose [6].

3.4. Work Flow

Figure 4 shows the work flow chart of WBAN. In the flowchart workflow is divided into two sections. First section is the WBAN where all the sensors devices will collect data and process them to the control center. While processing if any error occurs then it will read data again from the sensor and will forward for processing.

The control center will send the data to the desired location. If any problem occurs then it will generate an error where resend option should be needed again.

4. WBAN Standards and Technologies

As WBAN is a short range wireless networks so different types of wireless short range technologies can be involved in different stages. In this segment we will describe most common technologies such as Bluetooth, ZigBee, WiFi, IEEE 802.15.6 etc. that can be used to deploy WBAN.

4.1. Bluetooth

Bluetooth is an IEEE 802.15.1 standard commonly known as WPAN (Wireless Personal Area Network). Bluetooth technology [7] was designed as a short range wireless communication standard, anticipated to form a network with security and low power consumption. A typical Bluetooth network forms a Piconet where a Bluetooth device works as a master and another seven Bluetooth devices

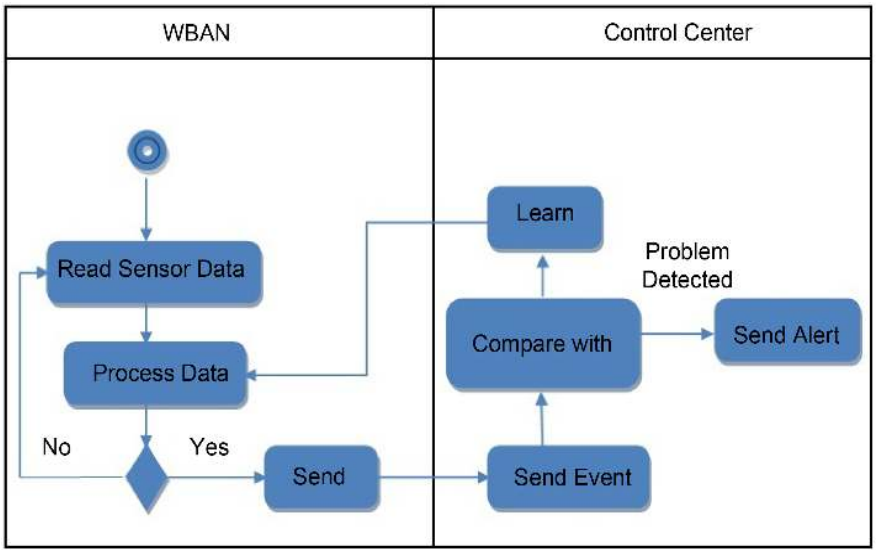

Figure 4. Working flowchart of WBAN.

work as slaves which gives each device to communicate with each other simultaneously. Another type of Bluetooth network can be formed with more than one Piconet known as Scatternet. In Scatternet a node of a Piconet (can be a master or a slave) joins as a slave in another Piconet. **Figure 5** shows how a Piconet and Scatternet are formed using Bluetooth nodes. Though, the basic Bluetooth protocol does not support relaying but it is possible to join together numerous Piconet into a large Scatternet, and to expand the physical size of the network beyond Bluetooth's limited range using this method [8].

Bluetooth devices operate in the 2.4 GHz ISM band (Industrial, Scientific and Medical band), utilizing frequency hopping among 79 1 MHz channels at a nominal rate of 1600 hops/sec to avoid interference. It is classified with three classes of devices with coverage ranging from 1 to 100 m and different transmission powers ranging from 1 mW to 100 mW with 3 Mbps data rate [9]. A very key feature of Bluetooth is that all the Bluetooth devices can communication with each other in NLOS condition. Bluetooth is suitable for short distance data transmission applications such as between servers of WBANs or between a WBAN and a personal computer.

4.2. ZigBee

ZigBee is an IEEE 802.15.4 standardized solutions for wireless telecommunications designed for sensors and controls, and suitable for use in harsh or isolated conditions. One of the biggest advantages of ZigBee network is its low power consumption. **Figure 6** shows a typical ZigBee network topology which consist of three kinds of devices or nodes such as coordinator, router and end device. One coordinator exists in every ZigBee network. It starts the network and handles management functions as well as data routing functions. End devices are devices that are battery-powered due to their low-power consumption. They are in standby mode most of the time and become active to collect and transmit data.

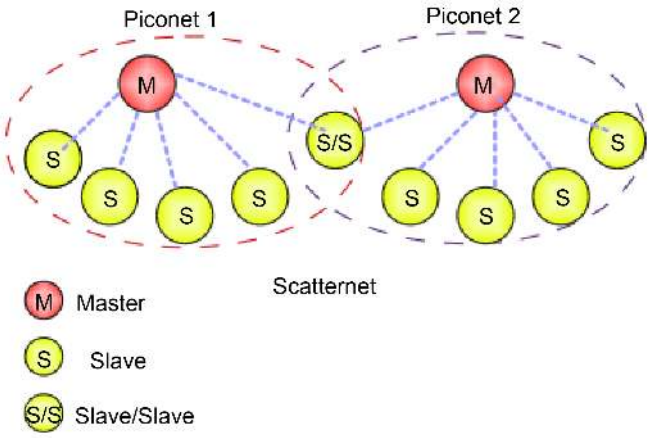

Figure 5. Bluetooth network.

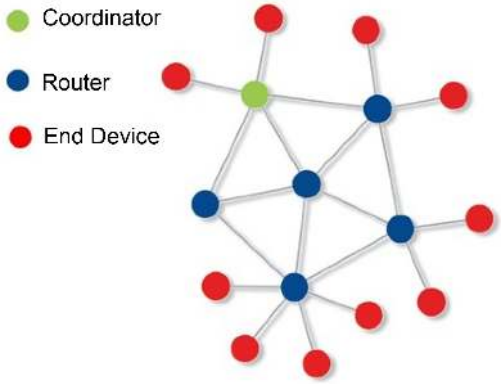

Figure 6. ZigBee network.

Devices such as sensors are configured as end devices. They are connected to the network through the routers. Routers help to carry data across multi-hop ZigBee networks. In some cases ZigBee network topology are formed without routers when the network is point to point and point to multipoint.

ZigBee is aimed at RF applications that require low data rate, long battery lifespan and secure networking. Through the standby mode, ZigBee enabled devices can be operational for several years [10]. ZigBee-based wireless devices operate in three different frequency bands such as 868 MHz, 915 MHz, and 2.4 GHz. Therefore, one substantial drawback of using ZigBee network for WBAN applications is due to interference with wireless local area network (WLAN) transmission, especially at 2.4 GHz. As ZigBee devices operate at low data rate so it can be unsuitable for large-scale and real time WBAN applications. But, it can be very much suitable for personal use like assisted living, health monitoring, sports, environment etc. within a modest range between 50 - 70 meters [11].

4.3. WiFi

WiFi is an IEEE 802.11 standard for wireless local area network (WLAN) [12]. Generally WiFi technology comes with four standards (802.11 a/b/g/n) that runs in ISM band 2.4 and 5 GHz with a modest coverage of 100 meter. Wi-Fi permits

users to transfer data at broadband speed when connected to an access point (AP) or in ad hoc mode. Figure 7 shows a WiFi network where WiFi sensor nodes and users can transfer data using internet by standard WiFi router. In some modified version, WiFi devices can be used in data acquisition applications that allow a direct communications between the sensors and the smart phones/ PC even without an intermediate router.

WiFi is preferably suitable for large amount of data transfers with high-speed wireless connectivity that allows videoconferencing, voice calls and video streaming. An important advantage is that all smart phones, tablets and laptops have Wi-Fi integrated; however the main disadvantage of this technology is high energy consumption [13].

4.4. IEEE 802.15.6 WBAN

IEEE 802.15.6 is the latest addition in WPAN which is known as WBAN standard that provides various medical and non medical applications and supports communications inside and around the human body [14]. This standard supports communication inside and outside of human body which can be used for different medical and non medical applications such as e-Healthcare monitoring, sports, environment etc.

IEEE 802.15.6 standard is classified by three physical layer standards. Each standard uses different frequency bands for data transmission with data rate 10 Mbps maximum. First one is Narrowband (NB) which operates within the range of 400, 800, 900 MHz and 2.3, 2.4 GHz bands. The Human Body Communication (HBC) is another standard which operates at range of 50 MHz [15]. The Ultra Wideband (UWB) technology operates between 3.1 GHz to 10.6 GHz which supports high bandwidth in short range communication [11].

5. WBAN Applications

As like other wireless networks WBAN is also capable of transmitting data, voice, video, picture etc. through radio communication path [16]. For this reason WBAN has introduced several numbers of innovative and effective applications. Broadly these applications can be characterized into two categories. They are medical and non-medical applications.

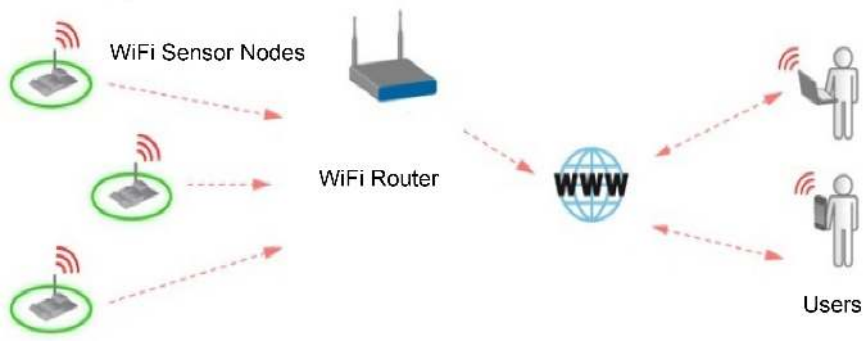

Figure 7. WiFi network.

5.1. Medical Applications

WBAN has conquered the medical area with a wide range of possibility. WBAN technology is improving the efficiency of doctor-patient activities such as remote patient monitoring, timely health status, notification, emergency calling etc. anytime at anywhere. In this paper some potential medical applications are described as follows.

5.2. Remote Healthcare Monitoring

WBAN can offer automatic medical service through remote monitoring of a patient's vital organs [17]. Sensors are placed on the body of patient that are capable of sending body organ status such as body temperature, heart rate, blood pressure, ECG signal for monitoring heart activity, movement sensor to monitor patient movement [18]. These sensors can be of two types such as on-body and in-body implants. On-body implants are wearable sensors placed on the body [19]. The in-body sensors are implanted in the body organ to measure vital parameters from the sensors. All the information can be monitored and stored from the control unit or remotely.

5.3. Assisted Living

WBAN has another exciting application in medical and healthcare service known as assisted living. Wearable medical sensors can be used at home to measure physiological data from patient's body and transmit/store them into particular medical center server/control unit in a regular interval. It helps the patient to stay at home and get continuous support instead of staying at hospital. In case of any emergency sensors implanted on the body of patient at home can raise alarm of urgent notification to the nearby medical center.

5.4. Telemedicine

Telemedicine is another fascinating application field of WBAN. It provides health care services over a distance with the help of information and communication technology. WBAN technology can be integrated in the sector of telemedicine like online video consultation with doctors, transmission of medical reports and images, remote medical diagnosis etc. [20]. This technology helps the patient to get treatment at distance where doctors can provide e-prescription by monitoring patient's condition from anywhere [21].

5.5. Non-Medical Applications

5.5.1. Sports

WBAN enable devices can be wearable. It is very effective to monitor the physiological activities of the wearer like heart rate, temperature, respiration rate, blood pressure, activity, and posture of any athlete in sports. Navigation, timer, distance can be also measured by using WBAN sensors.

5.5.2. Military

The opportunities for using WBANs in military are numerous. In a battlefield

WBANs can be used to communicate between soldiers and send their activities like attacking, running, retreating, and digging to the base commander. WBAN sensors are also helpful to monitor health condition, location, and temperature and hydration level of soldiers in the battlefield. Those sensors like camera, GPS, monitoring sensors, RF can be implanted with the military uniform. So in any military operation WBAN can provide more accuracy, survivability and connectivity [22].

5.5.3. Life Style and Entertainment

WBAN can also play a vital role in our daily life. It enables some basic services like navigation support while walking, driving, exploring a new city etc. [22]. Infant monitoring, wireless wearable music system, making video call using big screen TV, playback of audio and videos from portable devices to TV or Audio system are some examples of WBAN application [17].

6. Conclusions

WBAN is an emerging technology which is expecting to have a great impact on our society as well as in the field of medical and non-medical sector. In this paper an overview of WBAN has been outlined where we have highlighted the WBAN architecture and deploy requirements of this technology. We have also discussed about development and the technology adoption with different fields of application here.

The aim of this work was to offer a suitable and appropriate wireless technology in order to deploy network. For this reason we have described several short range wireless communication technology that can be adopted in WBAN. Through this paper it has been shown that many applications that are suitable to apply for WBAN. After all the narration we can summarize that for medical applications ZigBee and UWB are suitable where in the sector of lifestyle and entertainment Bluetooth and ZigBee can be appropriate.

In the end we feel that several non-technical factors would also play crucial roles in the success of the WBAN technology development such as affordability, legal, regulatory and ethical issues, and user friendliness, comfort and acceptance.

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