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# WIRELESS BODY AREA NETWORKS: A SURVEY

**Manisha[1], Ritika[2]**
[1,2]M.Tech (CSE)
[1,2]Department of CSE
PDM College of Engg., Bahadurgarh
[1]mani_sehra@gmail.com, [2] ritika.snp@gmail.com

***Abstract**: Advancement in wireless technology born a new generation of WSN which is appropriate for networking on the human body or in the human body. For data transfer among sensor nodes a point to point topology or multi-hop topology is used in these networks. In wireless body area network, only few sensors are used which are implanted in body or positioned on the body. These tiny sensors placed on patient's body measure vital signs like blood pressure, Glucose level, and pulse rate etc. Wireless body area network, WBAN, is a network designed by low-power devices that are located on, in or around the human body and are used to monitor physiological signals and motion for medical, personal entertainment and other applications and purposes In Wireless Body Area Network, Sensor nodes are typically powered with battery, which have insufficient life time. Even though renewable energy sources like solar energy or piezo-electric means are used as supplementary energy in WSNs, it is still some degree of reserve to consume energy judiciously. Proficient energy routing is thus a key requirement for a trustworthy design of a wireless sensor network.*

***Keywords:** WBAN, Hierarchical routing in WBAN, wireless body area network.*

## 1. Introduction

Advancement in wireless technology born a new generation of WSN which is appropriate for networking on the human body or in the human body. For data transfer among sensor nodes a point to point topology or multi-hop topology is used in these networks. In wireless body area network, only few sensors are used which are implanted in body or positioned on the body. These tiny sensors placed on patient's body measure vital signs like blood pressure, Glucose level, and pulse rate etc. These measured values are then forwarded to the medical server or doctor to further analyze the patient's condition. Wireless sensors provide continuous monitoring of patient at remote place. Use of topology depends on the application, for example to measure the postures of an athlete require a multi-hop topology. The sensed data is exchange among sensor nodes and then it reaches to base station or sink. Sensors can be implanted or placed on the athlete's body. One of the major applications of WSN technology is monitoring of human health [2]. Wireless body area network, WBAN, is a network formed by low-power devices that are located on, in or around the human body and are used to monitor physiological signals and motion for medical, personal entertainment and other applications and purposes [1], Fig.1. Healthcare applications have attracted researcher's attention because of the increasingly aging population prone to age-related diseases and could often benefit from continuous monitoring of physiological signals [2]. The use of WBANs may enable ubiquitous healthcare and could lead to proactive, and even remote, diagnostic of diseases in a nearly stage. Moreover, a WBAN may contain an actuator, which based on measurements and settings, can automatically release medicine or other agents. An example being an actuator to supply insulin to a patient with diabetes under the appropriate conditions. Additionally, WBANs provide health monitoring without interfering the patient's everyday activities. For real-time applications where the caregiver needs to receive information about the patient's health on a continuous basis, the WBANs should provide, among other characteristics, reliable communications that are relatively insensitive to link or node failures [3]. However, patient mobility increases the probability of packet loss, and it is preferred that the packet error rate should be kept less than1% [4]. Moreover, the WBANs must transmit at low power to protect the patients against harmful health effects associated with the radiofrequency (RF) emissions. Thus, the specific absorption rate (SAR) should be low [5]. SAR is the rate at which the RF energy is absorbed by a body volume or mass. Due to this limitation on the specific absorption rate, it is not possible to increase the transmission power beyond a certain level to overcome the transmission loss of the packets. To increase the network's throughput and reliability in the presence of packet losses and avoid single points of node or link failures, the author extend Cooperative Network Coding (CNC)as proposed in [6] to networks where there are many

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sources, many relay nodes and many sinks/destinations. The relays and sinks act as multiple-input-multiple-output (MIMO) nodes.

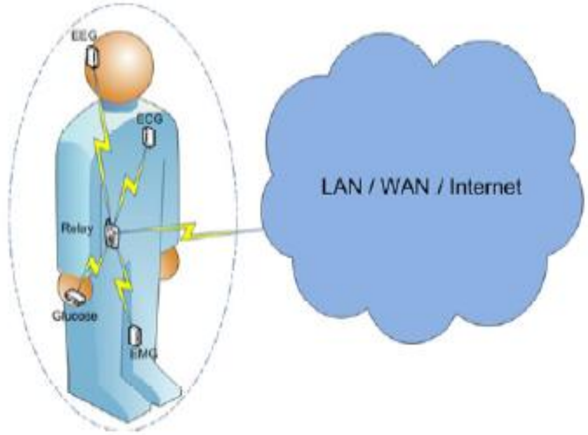


**Figure 1**: Wireless Body Area Network

***1.1 Standards for WBAN Communication***

A large number of communication standards are used for WBAN. Wearable devices which are based on microchips also rely on these standards. Most widely used standards are Bluetooth, ZigBee, MICS, and Ultra Wide Band (UWB) IEEE802.15.6.

***1.1.1 IEEE 802.15.1 (Bluetooth)***

IEEE 802.15.1 is a communication standard which is used for short range communication, typically within 10m range. The data rate of Bluetooth standard is3Mbps. The bandwidth of Bluetooth standard is high while latency rate is low. High bandwidth encourages use of bluetooth standard in UHC.

***1.1.2 ZigBee***

This standard is employed with a collision avoidance technique. ZigBee got the power to control complex operations related to communication. It utilizes very less energy in communication nearly about 60mW. The data rate of this standard is low nearly250kbps. ZigBee has the capability of encryption to give considerable protected communication [2].

***1.1.3 MICS***

MICS standard is particularly designed for communication in medical applications. This standard is specifically used for on body or in body communication in WBAN. This standard is used at distance of short range that is a range of human body MICS utilizes low power as compared Ultra Wide Band (UWB) so it radiates less energy that is good for human body tissues [4,7].

***1.1.4 IEEE 802.15.6 Ultra Wide Band (UWB)***

UWB is a high bandwidth communication standard and it is used in high data rate applications. UWB is best choice whenever a application requires a high bandwidth. In emergency applications, UWB is considered best choice to use for communication. UWB are implemented with Global Positioning System (GPS). The receiver of UWB band is very complex that makes it not good for use in wearable application [7]. It can be seen from figure 2 that BAN protocols should be more power efficient compared to existing commercial protocols.

## 2. Applications of Body Area Networks

WBAN applications span a wide area such as military, ubiquitous health care, sport, entertainment and many other areas. IEEE 802.15.6 categorizes WBAN applications into medical and non-medical or Consumer Electronics as can be seen in Table 1. The main characteristic in all WBAN applications is improving the user's quality of life [8]. Among the many possible applications that have been thought up for BANs are communication in hospitals, communication on aero-planes or spaceships, monitoring of patients at home (post-operative care), modern Warfare, monitoring of babies, interlinking of components in home entertainment products and athlete monitoring and sports analysis.

***2.1 Medical Applications***

Based on advances in technology (in micro-electronic miniaturization and integration, sensors, the Internet and wireless networking) the deployment and servicing of health care services will be fundamentally changed and modernized. The use of WBANs is expected to augment health care systems to enable more effective management and detection of illnesses, and reaction to crisis rather than just wellness [2, 3].

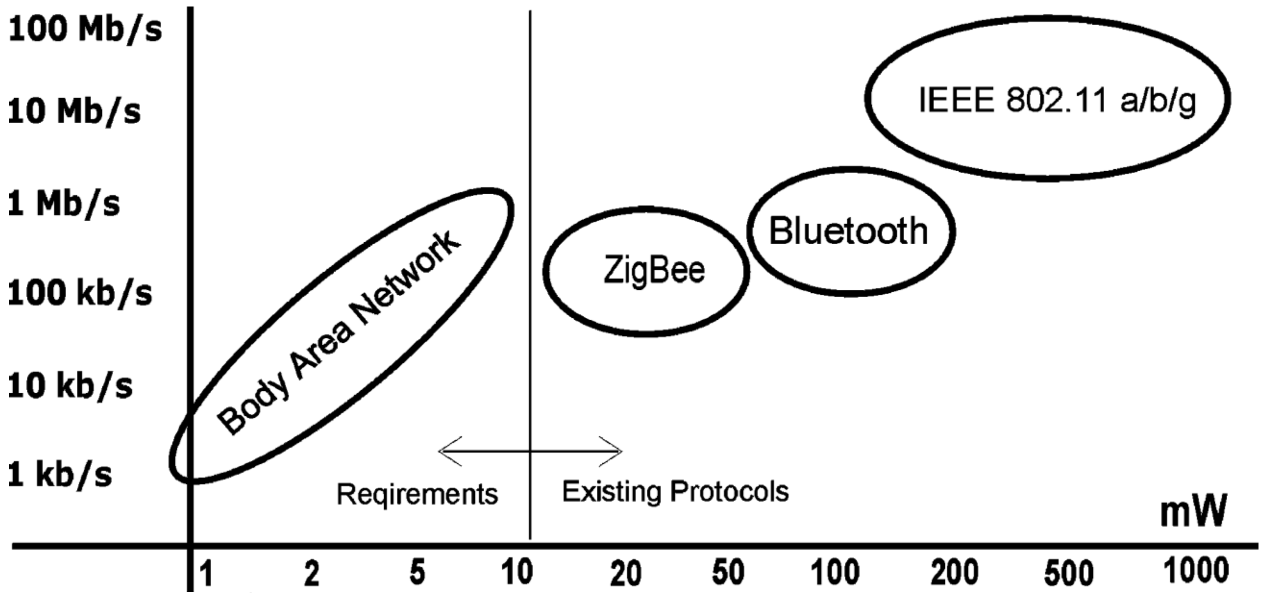


Table 1: Applications of WBANs

| | | |
|---|---|---|
| WBAN Application | Medical | Wearable WBAN |
| | | Implant WBAN |
| | | Remote control of Medical Devices |
| | Non-Medical | |

Using WBANs in medical applications allows for continuous monitoring of one's physiological attributes such as blood pressure, heart beat and body temperature. In cases where abnormal conditions are detected, data being collected by the sensors can be sent to a gateway such as a cell phone. The gateway then delivers its data via a cellular network or the Internet to a remote location such as an emergency center or a doctor's room based on which an action can be taken [3, 4].

*1) Wearable WBAN:* Wearable medical applications of WBANs can further be classified into the following two subcategories:

a) Disability Assistance,

b) Human Performance Management.

Some of these applications are mentioned below:

*i. Assessing Soldier Fatigue and Battle Readiness* – The activity of soldiers in the battlefield can be monitored more closely by WBANs. WBANs can also be used by policemen and fire-fighters [8].The use of WBANs in harsh environments can be instrumental in reducing the probability of injury while providing improved monitoring and care in case of injury.

*ii. Aiding Professional and A mature Sport Training* – The training schedules of athletes can easily be tuned via WBANs as they provide monitoring parameters, motion capture and rehabilitation. Moreover, the real time feedback provided to the user in these networks allows for performance improvement and prevents injuries related to incorrect training [7].

*iii. Sleep Staging* – Sleep is an important behavior and regular physiological function which consumes one-third of our everyday life. A large population is suffering from sleep disorders - an average of 27% of the world population. The consequences of such disorders can be quite severe and lead to cardiovascular diseases, sleepiness at work place and drowsy driving. The effect of sleep disorder on work performance is estimated to cost 18 billion in lost productivity. Therefore, sleep monitoring has gained great interest in the recent years. WBANs are capable of delocalization of the intelligence and instruments in their sensor nodes and removal of all cables [8].

*iv. Asthma* – A WBAN and accompanying sensors are capable of monitoring allergic agents in the air and providing real time feedback to a physician, which can help millions of patients suffering from asthma.

*v. Wearable Health Monitoring* – WBANs in conjunction with sensors and other devices on the human body can provide real-time health monitoring.

The cell phone receives glucose diagnoses from the glucose module which may then be stored or sent to a doctor for analysis.

*2) Implant WBAN:* This class of applications is relative to nodes implanted in the human body either underneath the skin or in the blood stream.

*Diabetes control* – 6.4% of the world's adult population, which represent 285 million people, suffered from diabetes in 2010. This number is estimated to reach 438 million by 2030, 7.8% of the adult population6. Research has shown Diabetes to result in long-term medical issues if not carefully monitored and treated7. Frequent monitoring provided by WBANs is capable of reducing the risk of fainting, enables proper dosing, and eliminates risks of loss of circulation, later life blindness and more complications.

*Cardiovascular Diseases* – Cardiovascular diseases are known as the major cause of death for 17 million people annually8, which can be significantly reduced or prevented with appropriate health care strategies. Myocardial Infarction (MI) can be greatly reduced by monitoring episodic events and other abnormal conditions through WBAN technology.

*Cancer Detection* – Cancer death rates are estimated to increase by 50%, reaching up to 15 million by 20209. WBAN based sensors capable of monitoring cancer cells in the human body will enable physicians to continually diagnose tumors without biopsy providing more timely analysis and treatment.

***2.2. Non-Medical Applications:***

Non-Medical applications of WBANs can be further classified into five subcategories as follows:

*1) Entertainment Applications:* This category consists of gaming applications and social networking. Appliances such as microphones, MP3-players, cameras, head-mounted displays and advanced computer appliances can be used as devices integrated in WBANs.

*2) Emergency (non-medical):* Off-body sensors (e.g. Built into the house) are capable of detecting a non-medical emergency such as fire in the home or flammable/poisonous gas in the house and must urgently communicate this information to body-worn devices to warn the wearer of the emergency condition [7].

*3) Emotion Detection:* Wearable sensing technologies have enabled emotion detection through the induction of physical manifestations throughout the body that leads to the production of signals to be measured via simple bio-sensors.

*4) Secure Authentication:* This application refers to utilizing both physiological and behavioral biometrics such as iris recognition, fingerprints and facial patterns. This is one of the key applications of WBANs due to duplicability and forgery, which has motivated the use of new behavioral/ physical characteristics of the human body, in essence multi-modal biometric, gait and electroencephalography [7].

## 3. WBAN ROUTING

Numerous routing protocols have been designed for Adhoc networks [7] and WSNs [8]. WBANs are similar to MANETs in terms of the moving topology with group-based movement rather than node-based movement [6]. However, WBANs have more strict energy constraints in terms of transmit power compared to traditional sensor and Ad Hoc networks as node replacements particularly for implant nodes can be quite uncomfortable and might require surgery in some scenarios. Therefore, it is crucial for WBANs to have a longer network lifetime to avoid constant recharging and replacement of nodes attached to a person. Additionally, a WBAN has more frequent topology changes and a higher moving speed, while a WSN has static or low mobility scenarios. Due to the aforesaid issues and specific WBANs challenges, the routing protocols designed for MANETs and WSNs are not applicable to WBANs.

## 4. Challenges of Routing in WBANs

1. *Postural Body Movements* – Node mobility, energy management and environmental obstacles increase dynamism in WBANs, including frequent changes in topology and network components that amplify the complexity of Quality of Service (QoS). Additionally, the link quality between nodes in WBANs varies as a function of time due to various body movements [2]. Moreover, some body segments and clothing result in signal blockage that intensifies RF attenuation. More specifically, the mobility pattern in WBANs changes with the order of movements within tens of centimeters whereas the scale of mobility in WSNs is in the order of meters and tens of meters.

2. *Sensor validation* - The sensing node in WBAN technology must have reliable wireless communication link. These sensing devices have inherent communication limitations in form for limited energy source and interference. These inherited issues in WBAN may cause false data transmission back to user. For health care application or patient monitoring application, it is very important that the readings of the patient are valid and then securely transmitted to medical server. It can overcome false alarms.

3. *Local Energy Awareness* – The proposed routing protocol has to disperse its communication data

among nodes in the network to balance power usage and minimize failure to battery supply drainage.

4. *Global Network Lifetime* – Network lifetime in WBANs is referred to as the time interval from when the network starts to the time the network is significantly damaged, which leads to network partitioning such that the destination cannot be reached. As battery replacement and charging is not feasible in implant medical devices, network lifetime is of more importance in WBANs compared to WPANs and WSNs.

5. *Efficient Transmission Range* – The low RF transmission range in WBANs leads to frequent partitioning and disconnection amongst sensors in WBANs, which results in similar performance to DTNs. In cases where the transmission range of sensors are less than a threshold value, there are fewer choices for routing to adjacent sensors which leads to a higher number of transmissions leading to overall temperature rise. Also, the fewer the number of neighbors, the lower the probability for packets to arrive at the destination within a certain hop count.

6. *Limitation of Packet Hop Count* – According to the IEEE802.15.6 standard draft for WBANs, one-hop or two-hop communication is allowed in WBANs. While, multi-hop transmission provides stronger links leading to overall increase in system reliability. The larger the number of hops, the higher the energy consumption. However, the limitation of packet hop count has not been considered in most WBAN routing protocols. Additionally, half-duplex devices in WBANs reduce the bandwidth as successive hops are introduced.

7. *Heterogeneous environment* – Specific applications of WBANs may require heterogeneous data collection from different sensors with different sampling rates. Therefore, QoS support in WBANs may be quite challenging.

8. *Limitation of resources* – Data capacity, energy and device lifetime of WBANs is strictly limited as they require a small form factor. Due to limitation of available resources in WBANs, therefore, WBAN nodes are bound to fail due to unavailable battery power, memory and bandwidth limitations, which are major threats to QoS.

## 5. Conclusion

In this paper, we have surveyed the introduction of Wireless Body Area Network, Applications of WBAN and Challenges of Routing in WBANs. The architecture of WBAN is quite different from MANET and WSN so, the routing protocols designed for MANETs and WSNs are not applicable to WBANs. In Wireless Body Area Network, Sensor nodes are typically powered with battery, which have insufficient life time. Even though renewable energy sources like solar energy or piezoelectric means are used as supplementary energy in WBANs, there is still some degree of reserve to consume energy judiciously. Proficient energy routing is thus a key requirement for a trustworthy design of a Wireless Body Area Network.

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