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A Comprehensive Review on Wireless Body Area Network - Technologies, Challenges, Application and Energy Saving Techniques

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Abstract

A Wireless Body Area Sensor Network (WBASN) is becoming a routine part of everyday life due to its versatility of uses, particularly in the field of medical care for continuous patient monitoring, providing clinical assistance in patient care, and to improve the quality of patient's lives. Due to the low power battery capacity of biosensors comprising in WBAN, making replacement of batteries poses a challenge, specifically for sensors implanted inside the human body. Also, these networks produce a large amount of sensory information, which requires the network to balance the load to perform optimally and last longer. This review article gives an outline about energy management of wearable or non-wearable sensors, load balancing, routing, and security issues in wearable Remote Body Area Network (RBAN). It also highlights the fundamental issues, energy maintaining challenges in such delicate sensitive BAN, and a wide scope of Internet of Things (IoT)-based applications in the field of clinical, sports, lifestyle, and diversion. Various energy-improving routing algorithms utilized in WBAN to profit the networks Quality of Service (QOS) and the correspondence advancements utilized in associating wearable WBAN in the IoTapplication are also discussed in detail.

Keywords:Wireless Body Area Network - Architecture, Challenges, Security, Quality of Service, Applications, Routing protocols survey

I. Introduction

In recent years, progress in Information and Communication Technology (ICT) has contributed to improvements in the healthcare domains such as patient administration like infection diagnostics, computerized information assortment, and patient monitoring. Therefore, an expanded life is seen in numerous spaces of the world. Presently, 11.7% of the total population is above 60 years old and it is relied upon to stretch around 21.1% before the finish of 2050 [1]. The innovation of Wireless Body Area Networks (WBAN) has acquired a great deal of acknowledgment as a result of its appropriateness and wide range in the applications of both clinical and non-clinical. WBAN is composed of lightweight embedded sensor gadgets that can be implanted or fixed on the body that can convey information through wireless media [2]. Healthcare monitoring involves installing a variety of biosensor devices on human clothing, even implanting them inside the body, around the human body, to sense the function of various organs.Some WBAN sensor nodes, particularly in clinical uses, are committed to the continuous recording of the detailed condition of the patients' body such as heartbeat, Electrocardiogram (ECG), Electroencephalogram (EEG), movement, temperature without influencing their typical day-by-day way of life [3]. The sensor nodes over the body form the network, and through a wireless medium, these all are connected to the centralized station called Base Station (BS). The collected patient data are accumulated in the BS for further processing. The clinical experts obtain the essential data from the BS using the Internet service for nonstop checking of patient health conditions. [4-5]. Since the energy level of the sensors would be depleted, it is difficult to recharge or replace the battery of the nodes while functioning. Especially in the case of replacing the battery of nodes inside the human body required significant medical procedures and its cost is also very expensive. In light of this, it is essential to find new ways to improve energy efficiency in biosensors without affecting the conveyance proportion of e-medical services applications. Also in medical applications, since patient data are sensitive, they can be modified by an unauthorized user while they are transmitted via an insecure wireless network, and due to the heterogeneity of sensor nodes each requires varying levels of quality of service (QoS) to maintain data integrity, security, reliability, and efficiency [6]. Thus, the designing of the QoS protocol is a major challenge for the researchers.

There are many energy efficiency and QoS assuring protocols that have been developed for different modules of clinical application. The contribution of this review work is outlined below.

- Give a concise foundation of WBAN innovation in medical services and its design architecture that conforms to the standard of IEEE 802.15.6. This compact introduction and architecture clear out the function of WBAN in medical services to the readers.
- Present the different challenges that occurred during the practical implementation of WBAN in medical care. The applications of WBAN have been discussed comprehensively.
- Investigate and present the various routing schemes by considering the specific issues of energy efficiency,

mobility, security, clustering, QoS, and network lifetime in WBAN.

In this paper, six sections are presented. The architecture of the WBAN technology is discussed in section 2. In Section 3, the challenges while implementing WBAN in medical services have been explored. A comprehensive discussion of the WBAN application is done in Section 4. In Section 5, the classification of routing schemes for WBAN and prospects for a future research plan in improving energy efficiency are discussed. The review article is concluded in Section 6.

II. Wireless Body Ares Network – 3 Layer Architecture

WBAN communication model needs to consider point-to-point link and environmental viability in the propagation model and communication scenario. There are several ways to propagate WBAN: Narrow Band (NB), Ultra Wide Band (UWB) and Ultra High Band (UHB).With NB communications, the body attenuates less of the signals because the carrier frequency is low. Communication using UWB can handle higher data rates and require less power.Using UHC of communication, signal transmission takes place through electricity coupling across a medium of human skin by means of electrodes using capacitive or galvanic coupling without antennas. WBAN channel models can be divided into three types of setups: on-body, in-body, and off-body. Sensors linked to the sink node on the body surface are used for on-body communication [49]. Sensors and co-ordinaters of body implants when placed within the body may communicate within three meters of the human body for in-body communication and off-body communication, respectively.

Layer 1(WBAN layer): Biological sensors are called nodes in intra WBAN, and these nodes extend into or out of a human body or located on the surface to sense psychological vitals of the human body and transmit the sensed information to the local coordinator WBAN hub. The WBAN hub is a personal server that acts as a gateway allows interaction with the next connected layer.

Layer 2 (Connectivity layer): In the connectivity layer, local coordinators or sink nodes receive the sensed data from the WBAN hub, aggregate it, and send it to BS through several Access Points (AP).As soon as the data are sent from BS to the clinical service center, they are stored in a database on a cloud, a local server or a web server.

Layer 3(Service layer): In this service layer, the clinical experts can get the patient's healthcare information remotely and provide the treatment according to their condition or emergency basis. Moreover, Tier-3 permits re-establishing all important data of a patient which can be utilized for treatment [7-8].

Figure 1 show the design of a WBAN observing architecture. The WBAN system architecture can be split into three levels, intra WBAN layer, connectivity layer, and service layer.

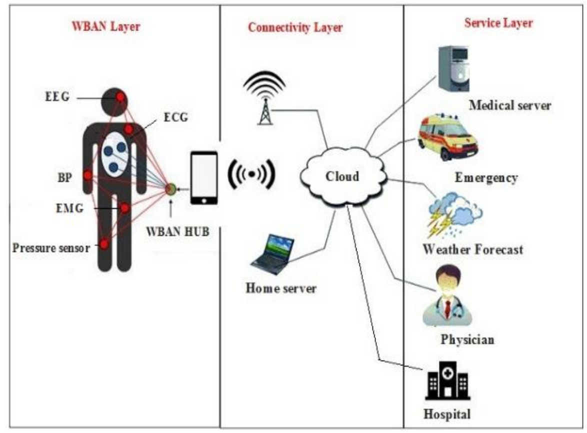


Fig.1. Three Layer Architecture of WBAN

A typical WBAN comprises lightweight sensor nodes with a low power operation, each node obtaining a particular functional parameter of the body. WBAN is the field wherein observing time is unlimited or is more time contrasted with other accessible devices and the sensor size is little which makes them simple to carry around [9].Table -1 show various types of on-body and invasive sensors.

TABLE I- On-body & Invasive sensors and its function

Wearable /Non-invasive sensors	**Function**
Electrocardiogram (ECG) sensor	Records an electrical potential from the heart
Blood pressure sensor	Measure human blood pressure pulse signal
IR Temperature sensor	Capture the human body temperature
Blood glucose sensor	Constantly check blood sugar levels within the body
Electroencephalogram (EEG) sensor	Records an electrical potentials of brain activity
Electromyography (EMG) sensor	Capture the muscles activity
Pulse oximeter sensor	Detect the flow of blood
O_2, pH value sensor	To detect the changes in the O_2 levels occurring in the respiratory organ and pH to sense extracellular acidification rate.
Accelerometer	Measures the acceleration of an object on-axis
Pacemaker	Stimulating the heart muscles by a small electrical device to maintain suitable heart rate
Electronic pill	Collect the information within the body
Cochlear implants	Stimulate the cochlear nerve
Deep brain stimulator	Detect movement disorders associated with Parkinson's disease (PD)
Implantable defibrillators	Detect the abnormalities of chest function
Retina implants	Substitute for photoreceptors

III. Challenges in WBAN

The efficiency of the WBAN is significant for both patients and medical care. Figure 2 illustrates WBAN's major challenges when it goes for practical implementation. These challenges are arranged in five important factors like energy, mobility, security, data communication, and quality of services.

A. Energy

Energy is an extremely scant resource for any kind of sensor network and must be managed wisely to extend the sensor node's lifetime for the continuous function and completion of a specific mission.

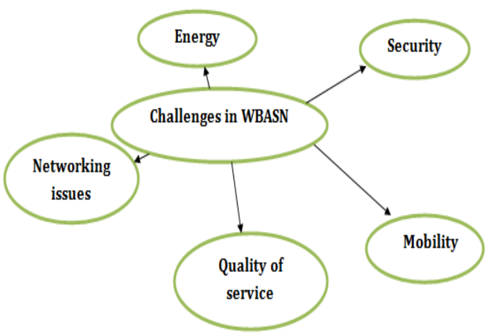


Figure 2 WBAN major challenges

The wearable sensors nodes are not difficult to replace when their battery is down, but in the case of embedded sensors in the body, replacing the battery may even require a significant medical procedure and in this way it's expensive. Energy harvesting is the technique of endowing sensor nodes with the ability to extract power from the surrounding environment sources of energy from solar energy, wind energy, mechanical vibrations, and electromagnetic fields [10-11].

B.Security

To ensure the security of patient health information, WBAN needs definite measures to ensure the safety of data collection and privacy of patient records is upheld at all times. For example, a patient might entail their details should not be shared with insurance agencies who might utilize this data to control his/her from the insurance coverage. Mostly the data collected inside a WBAN framework is very sensitive, and whenever spilled out to an unauthorized person could prompt a few effects for the patient life, for example, losing employment, public embarrassment, and psychological instability [12-13].

C. Quality of Service (QoS)

The WBAN deals with heterogeneous data, so the QoS parameters are not the same for all types of applications. It is necessary to incorporate QoS providing features in the network through efficient routing and security-based algorithms to enable self-correcting, data integrity, and traffic control [14].

D. Mobility

Mobility in a WBAN allows the patient to move wherever they want at all times. This impacts the wave propagation characteristics due to environmental obstacles which lead to data loss and increase the error rate [15].

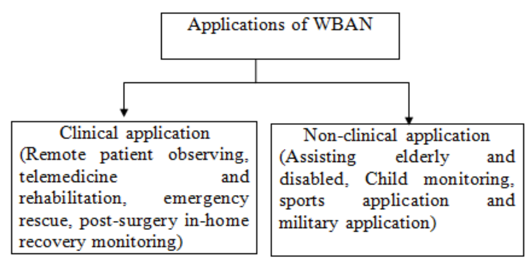
E.Networking Issues

The performance of the routing protocol could influence when the quantity of nodes increases in WBAN. Disrupting the communication between the sensor nodes and the medical service center leads to delay in data delivery, data loss, which affects the patient life. WBAN applications must, therefore, maintain the flexibility to access data at any time and under any condition [16]. Path losses occur when a wave's power density is reduced. The amount of path loss that occurs as a result of different impairments greatly influences WBAN. Since WBAN devices are commonly placed inside or on the body surface, loss between these devices can negatively impact communications and could compromise UHC performance monitoring. Since both distance and frequency play a role in path loss, WBAN differs from traditional wireless communication. In sensor technology, frequency matters due to the effect it has on body tissues.

IV. Applications of WBAN

WBAN is suitable for both clinical and non-clinical applications. In table 2, the specific application areas of WBAN are shown in clinical as well as non-clinical contexts.

TABLE II Applications of WBAN



The application of WBAN in the clinical field is remote patient observing, organ implantation monitoring, dosage control, telemedicine, medical care services, rehabilitation and therapy, and chronic disease surveillance. Throughout the world, there is no remedy for evading and treating ongoing diseases. With the development of WBAN, clinical therapy for chronic illnesses and the anticipation of their development is becoming more trustworthy. In helping the elderly and disabled, WBAN plays a crucial role. With the advancement of implanting optic sensors, the visionless person can see the surrounding atmosphere and street information in continuous, to identify the route to reach their destination. Supporting an elderly care system is essential for detecting their activities and updating their data. Locating the old, and keeping track of their activities provides security and wellbeing for our elderly. The WBAN is also helpful in monitoring kids for their safety and security. By the wearable sensor modules, a parent can easily locate the child's steps and their temperature through the mobile phones automatically when there is an abnormal [8-9].

V. WBAN – Routing Protocols Survey In Medical Care

Routing algorithms in WBAN are classified based on the mechanism, network performance, and lifetime by considering the specific issues [17]. Figure 3 shows different types of routing algorithms in WBAN.

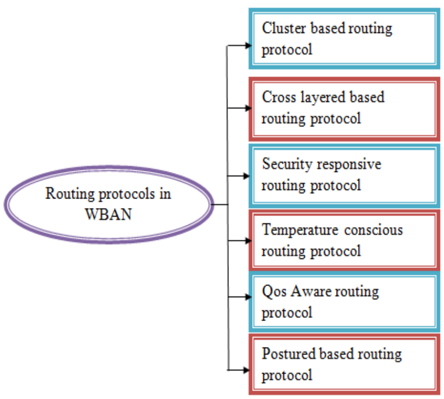


Figure 3 WBAN Routing protocols

A. Cluster-Based Energy-Efficient Routing Protocol

The clustering-based routing protocol is a suitable one for reducing energy consumption levels and also increasing the sensor node lifetime. This routing method divides the whole network into clusters. Cluster members and cluster heads are part of each cluster. From the sensor nodes, the cluster head collects, aggregates, and forwards the data to the sink node [18].

In [19], the authors presented data aggregation with a privacy-preserving algorithm for wearable sensor networks. This model divides the entire network into several parts called clusters including cluster head, sensor nodes with tree structure. A cluster head is chosen based on the trust value that is the greatest at the time of network initialization. The cluster head verifies the integrity of data that is collected from its cluster members to control the range of malicious nodes. In [20], the authors proposed a clustering-based ant colony optimization algorithm for WBAN. Using the algorithm, a cluster group is established and the clusters are arranged to send only critical patient data to the cluster head, then it forwards to the sink node through the selected optimal path by the ant colony optimization method. A protocol called Energy-Harvested Aware Routing Protocol (E-HARP) is proposed for the selection of dynamic cluster heads and the routing of data cooperatively [21]. Table 3 shows different approaches to clustering-based routing protocols for WBAN.

TABLE III Analyses of cluster-based routing approaches

Algorithm	Objectives	Limitations
Data aggregation [19]	To avoid data leakage Privacy- preserving of data from attacks in data aggregation	High energy consumption
Ant colony optimization algorithm [20]	Maximize the network lifetime by finding the optimal path	Applicable only for indoor hospital
E-HARP [21]	Minimize energy consumption and transmission power. Improve network stability.	Node temperature is not considered
Wireless energy harvesting [22]	Decrease the data latency Improve the energy efficiency of node battery	Data priority is not considered
SEAR [23]	Resolving the problem of link failure	High end to end delay

B. Cross Layered Based Routing Protocol

The WBAN performance could be degraded in the situation of high path loss and patient mobility. In cross-layer protocol, functionality of two or more layers within a protocol pile is used to cross or merge. Based on the characteristics of the communication channel, a routing protocol designed with cross-layer characteristics can improve the overall WBAN performance, maximize throughput and minimize power consumption by solving both the network and MAC layer issues [18].Typicallythe cascading data information retrieval that controls access and assigns slots dynamically (CICADA) is designed for wireless sensor networks that support multiple users. A tree-structured network is used, with the nodes arranged in a tree and the duration of transmission cycles known, allowing slots to be synchronized. It is the parent's responsibility to inform the child node where the message should be forwarded. Wireless Autonomous Spanning Tree Protocol (WASP) [24] is an updated version of it. The table 4 shown the different routing protocols based on cross layered.

TABLEIV Analyses of cross- layered based routing approaches

Algorithm	Objectives	Limitations
CICADA [23]	Use TDMA access technique to avoid collision	Emergency data is not transmitted on time Medium level of energy efficiency
WASP [24]	Handling multiple media access	Poor traffic heterogeneity Mobility is not support
PECLRP [25]	Ensure reliable data dissemination Customized medium access for intra and inter body network	Data priority is not considered Link condition is not considered
AAT [26]	Better transmission reliability with low power consumption	Delay in the delivery of packet

C. Security Responsive Routing Protocol

WBASN architecture faces several challenges related to security and confidentiality. The goal of a security-aware routing protocol is to build privacy and reliable data routing in the WBAN.The medical data of patients are periodically monitored using body sensor devices. Then the data is categorized based on its content and its sensitivity level. The information about the patient is transmitted from the mobile sink node to the medical center, allowing the medical professionals to monitor and treat them remotely. The security-based routing protocol protect the patient's data from malicious node attacks.This problem has been the subject of several research efforts, ranging from privacy and quality of service (QoS) to trust management and integrating WBANs with mobile devices.Table5 Shows various security-based routing protocols for WBAN.

TABLE V Analyses of security-based routing approaches

Algorithm	Objectives	Limitations
EPPA [27]	Privacy- preserving data aggregation	Supports only addition aggregation Increase communication overhead
MPPA [27]	Secure data aggregation use non- addition methods	Energy consumption is more than EPPA
Kruskal's [28]	Regulate the transmission efficiently between the sink and medical center	Priority of patient data
P-AEEF [29]	To preserve the patient's data from unauthorized access	High energy consumption

D. Quality of Service (Qos) Aware Routing Protocols

QoS-based routing is a big challenge in WBAN due to a lack of resources. The QoS is required in the WBAN to incorporate efficiency, data priority, reliable data link transmission, and data integrity, less transmission delay. Many QoS assurance protocols exist, such as the Priority Routing Service Framework (RSF) for specific QoS provisions to users. By combining QoS metrics, wireless channel status, and data packet priority, the routing path can be identified; however, high overhead is associated with the control packet [30].Table 6 shows some of the QoS aware routing protocols for WBAN.

TABLE VI Analyses of QoS-based routing approaches

Algorithm	Objectives	Limitations
DMQOS [31]	Control the packet delay Route discovery and path maintenance	High network traffic
ERP [32]	Minimize network traffic and power consumption	Didn't support inter body communication
OCER [33]	Consider inter body communication of patients	Support only for indoor hospital
OEEQR [34]	Reliable critical data delivery	Low convergence rate

E. Postural-Movement Based Routing Protocol

In WBAN the connection between two nodes frequently deals with the issue of apportioning or disconnection due to the human body dynamic postures movement. So, the researchers have attempted to tackle the issue of connection detachment by characterizing cost function, which is periodically changed. With the posture-based protocols, the nodes and the BS establish a stable path between them to forward data packets with minimum cost [35].

Designed to handle subdivided networks, OBSFR (On-Body Store and Flood Routing) is presented in [36]. This routing mechanism involves sending multiple copies of the same packet through multiple paths to the receiver node (sink). Each packet consists of a list of hop IDs which helps to identify the most efficient path to the destination. As soon as the receiver receives a data packet, it buffers it and analyzes the IDs list to find the node whose IDs are not available. A broadcast scheme is used to send the packet forward. Considering human movement, an opportunistic routing algorithm is proposed [37]. In this network model sensor nodes on the chest are used to detect information that is sent to the sink hub on the wrist where it is gathered and processed. In human motions, the wrist is at the front or back of the body, depending on the direction of movement. By using the relay node, the transmission of the data packet between the sensor node and the sink node is simplified.WBAN posture basedrouting protocols are presented in Table 7.

TABLE VII Analyses of body mobility-based routing approaches

Algorithm	Objectives	Limitations
OBSFR [38]	Routing based on node location with patients' postural mobility	Forwarder node is changed frequently due to mobility
ORBAN [37]	Reduce the energy consumption of the network and extend its life	Limited number of sensors node
ETPA [38]	Efficient route selection and energy management	Packet throughput is less
Pm-EEMRP [39]	Reliable data delivery even in patient mobility	Support only for intra network

F. Temperature-Conscious Routing Protocol

The thermal aware routing algorithm is crucial to WBAN. The biosensors inside or on the human body will emit electromagnetic radiation during wireless communion that could harm the patient's body and also affect the function of sense organs . To ensure the rise in temperature and radiation various thermal aware protocols are developed to prevent the patient body from radiation effect. In [40] Thermal-Aware Routing Algorithm (TARA) is used to prevent temperature rise caused by the fixed bio-medical sensor. During data communication, protocol defines the overheated nodes as hotspots and tells the path to direct the data from these nodes. TARA only concentrates on detecting temperature rises so it faces the problem of increase in network lifetime, packet drops, and reliable transmission. In [41] this article the author presented the Least Total Route Temperature (LTRT) algorithm, which combines the technique of shortest-path routing algorithm and the least temperature route (LTR) [42]. This protocol selected the data transmission route between the source and destination by considering the feature of the least temperature path. When the node is transmitting or receiving data, its temperature increases by one unit, and when it is not transmitting, it decreases by one unit. Table 8 list outs some of temperature based WBAN routing protocols.

TABLE VIIIAnalyses of temperature aware routing approaches

Algorithm	Objectives	Limitations
TARA [40]	Analyze and divert the data packet away from the hotspot region based on the temperature rise of the node.	Hotspot avoidance is failed. Packet drops is high Network life cycle not improved
LTRT [42]	To select least temperature path High packet delivery rate and throughput	Improve network life cycle
MATTEMPT [43]	The packet is routed outside of the hotspot area.	Nodes are not evenly distributed between loads in hotspots. Route selection is poor in terms of hotspots.
IRC [44]	The reduction of radiation exposure caused by implanted sensors	Network latency is high from end to end
ATAR [45]	To reduce the temperature of the sensor node	High end-to-end latency with limited network life.

G. Energy Issues That Need To Be Researched In The Future

Because the application areas are very diverse, the WBAN network's commercialization has increased its user base. There has been an increase in network traffic in the communication channel due to the number of users, which has induced a higher collision rate, more data loss, and increased interference among the subchannels used by the different technologies, such as UWB, ZigBee, and Bluetooth. In the future, WBAN may not be able to provide the type of communication required.

Due to the particularity of WBAN, which is an important application of WSN in medical care, the energy efficiency concept of sensor nodes implanted on or in the body needs to be taken into consideration for regular updating, optimization, and enhancement. Numerous energy-efficient routing plans have been developed since the improvement of WSN, and the improvements have grown to be more and more impressive. The WSN technology has great potential to enhance the efficiency and reliability of data communication in WBAN.

The researchers are concentrating on the aggregation of data, mobile sink-based routing, and data priority of the WBAN medical care to improve energy efficiency and load balancing. The data aggregation gathers the cluster data packets and assembles them in a well-organized and cost-effective way. In health care applications the continuous sensing the vital signs of the human body organs are not uniform that is heterogeneous, here the cluster or mobile sink-based routing techniques are used to identify the cost-effective route to reach the destination, that may face the various issues of changes in topology, patient mobility, node failure, and packet delay [46-48]. Still, there is a challenge in minimization of node power consumption, packet delay, reducing redundant data transmission, traffic congestion, and improving the network lifetime in WBAN.

VI Conclusion

This work has an emphasis on WBAN technology, energy-saving, major challenges, and applications. WBASN can change the medical services issues of future generations with the least expense. The major challenge in WBASN is designing a routing algorithm because of exceptional on-body and in-body limitations. Energy consumption and efficient data routing are significant in WBAN to protect the life of humans in health care applications. Numerous routing protocols, including those developed specifically for WBANs in clinical applications, were categorized according to their energy efficiency and discussed in detail in this survey. The WBAN energy-efficient routing protocol was categorized depending on various factors such as temperature-based, link, routing matrices, mobility, cluster, and QoS-based algorithm. It also emphasizes how the routing protocol involves in the improvement of energy-efficient, reliable data transmission, and low-cost WBANs. Hopefully, this review will give researchers a better understanding of how energy-efficient routing algorithms are implemented for WBANs in medical applications. Future research will intensify efforts to optimize routing in WBAN and to reduce energy consumption, thus extending the lifetime of networks.

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