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Wireless Body Area Networks For Healthcare: A Review

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Abstract:

To provide the practical solutions to the difficulties faced by current available medicinal service- based frameworks, Vital information of patient ought to be conveyed to the concerned destination continuously in real-time. This gives rise to the need for a system which allows any patient to get monitored over the internet with the help of a network called as Wireless Body Area Network (WBAN). WBAN comprises of several Sensor Nodes (SNs) which consume low power as compared to other sensing devices. The utilization of these networks includes the assistance of human safety in various situations.

Keywords: Wireless Body Area Networks, Sensor Nodes, energy efficiency, fault tolerance.

1. Introduction

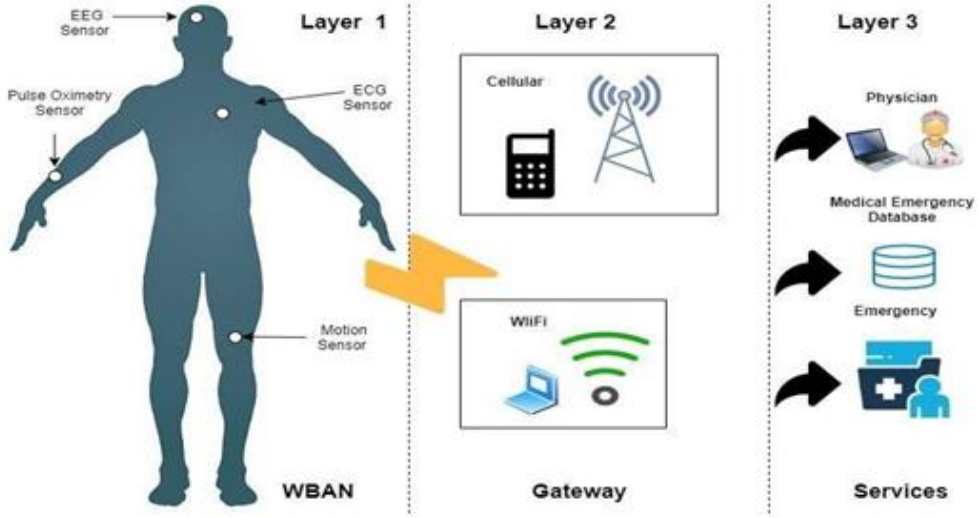
With the surge in a variety of diseases and the ever-increasing resistance of the infect ants such as bacteria, viruses, fungi, etc. against the traditional lines of treatment, preventive healthcare must be fast-tracked. This gains special significance in the era of rising healthcare costs and miniscule health insurance coverage. The resultant health crisis hence attracts researchers, industrialists, and economists towards smarter healthcare solutions, which should be affordable and flexible. The preventive monitoring of patient's vital parameters with real-time updates of medical records remotely offers an economical solution to the challenges that health care systems faces. Remote monitoring of vitals finds importance not just in the preventive healthcare of sick patients but also in athletes, military personnel, etc. who can use the readily available statistics for enhancing their stamina and agility [22]. A WBAN needs high degree of reliability because of its direct relation with the quality of patient monitoring. A little carelessness can lead to fatality. So, main goal is to monitor data correctly. So, to deal with high degree of reliability and correctness of data the protocol needs to address the following factors: fault tolerance, quality of service (QoS), and security. To deal with the concept of fault tolerance we need to address three different aspects i.e. that is fault, error, and failure.

1.1 Wireless Body Area Network (WBAN)

Generally, WBAN contains sensor nodes or sensor based network which attached any body to internet for data transfer. This type of network needs both way communications i.e. from sensor to sensor and sensor to coordinator. Furthermore, the Conventional Monitoring Systems in hospitals do not reveal the complete picture of the patient's health status due to infrequent monitoring of body functions. Due to this scenario, average healthcare expenses surge, so the overall load on healthcare management of a country

also grows. This acts as a catalyst to upgrade current healthcare systems in order to detect diseases at an early stage.

Figure 1: Wireless Body Area Network Architecture [22]



Smart healthcare has attracted more attention owing to its merits like mobility, flexibility, and ease of monitoring of the patient. It is popular since it makes use of a variety of latest technologies like cloud computing, Internet of Things (IoT) and big data processing, which focus on building an advanced disease care platform. It practically involves sensing technologies and automated devices to perceive and identify the physical properties of the patient and then perform several calculations, process those calculations, and mines the knowledge through those calculations, which helps us to cure the patient more efficiently than the traditional monitoring system [22].

Wireless technologies like Wireless Sensor Networks (WSN), Wireless Personal Area Networks (WPAN), and the internet can also provide the way by which we can create an economical solution for the above-mentioned problem. These technologies suggest using tiny, low cost, smart, low power micro-sensors and actuators to construct a sample of physiological data and send it to some server which can be a medical server through wireless communications which will further perform some analysis to inform back to the patient to have some primary care depending upon the data received. WBAN is the most recent invention which caters to such situations, which helps to detect some biological symptoms and informs the patient about most fatal diseases like cancer, asthma, and many more.

1.2 WBAN R Requirements

We mainly have two aspects on which a model or system can be built so in the case of WBAN. Below are the two basics requirements for WBAN.

1.2.1 Design Requirement of WBAN

In WBANs, Sensor nodes are responsible for collecting vital information of patient and further communication with the coordinator node. For an effective and reliable system latency and transmission schemes of data plays an important role. So, for system to be performing over a long period of time it should be reliable enough to deal with certain uncertainties. Deployment and adoption of WBAN may require addressing some design issues. So, the sensor nodes involved must be small, thin, non-invasive, wireless-enabled,

and should operate at a very low power level [21].

- **Energy Efficiency:** Energy efficiency should be the first goal for any researcher to design WBANs because of their small size and battery operable nature. As any patient can be on bed for long period of time so energy dissipation should be minimum always. Many protocols and designs for the same has been proposed throughout the time to minimize the energy consumption one should deal with sensor node's transceiver because it is the main source of power consumption and for that we have to deal with physical and MAC layer. Physical layer provides fewer windows for the same whereas MAC layer can be more optimized as several transmission techniques are proposed with time.

- **Reliability:** There are two major two aspects on which reliability of WBAN depends these are transmission of data along with data packet loss rate. So there is a need for appropriate MAC layer design along with data transmission techniques so that to minimize Packet Loss and Network Failure.

- **Scalability:** Scalability is an important prerequisite for WBANs. The requirement of sensor nodes always depends on the criticality of the patient i.e. more the patient critical more will be the sensor nodes required. So the model for WBAN should allow us to add or remove the sensing nodes whenever required. The MAC layer is capable of achieving scalability.

- **Quality of Service (QoS):** MAC layer plays an important role to achieve high degree of QoS. MAC layer techniques like TDMA and polling put forward packet loss and packet delay to the coordinating node. However, Techniques like CSMA allows a node only when channel is free. Random access techniques always results in variable packet loss and packet delay.

1.2.2 Technical Requirements of WBAN

WBAN consists of various heterogeneous devices connected all together to work as a node. Therefore technical requirement for every node is different. Some of the basic requirements are shown in the table below in Table 1 [16].

Table 1: Technical Requirements for WBAN

Parameter	Requirement
Working Space for WBAN	In, on, or around the body
Network size (Number of Nodes)	Modest (generally <64 Nodes)
Data rate	Always Scalable from a few kbps to 10 Mbps.
General Lifetime of Nodes	Depends on node i. For wearable, it's long enough ii. For Implanted it should beultra-long
Frequency Bands	Global Unlicensed and Medical bands
Maximum Power consumption	Is always Scalable depends upon mode of operation i. Between 0.001–0.1mW for standby mode ofoperation ii. up to30mW in case of fully active mode

Topology	Star, Mesh, or Tree
Device duty cycle	Adaptive, Scalable

1.3. Challenges in WBAN

WBAN is an emerging technology and lots of issues are still need to be addressed. Many problems still require a better solution. The nodes in WBAN are severely constrained by energy. Reducing the energy consumption of the nodes to prolong the lifetime is considered a critical challenge while designing protocols for WBAN. The fig. 2 depicts various challenges in WBAN.

- **Effective and Appropriate use of Bandwidth:** Higher frequencies always cause problems during IBC in majority of the communication systems of WBAN due to heat generated by both high frequency and body temperature. The IEEE 802.15.6 standard for WBAN offers a data rate of IBC as 1312.5 kb/s in the 21 MHz frequency band. According to work done by previous researchers minimum signal attenuation is achieved between 80–90 MHz [7]. In the capacitive method, the carrier wavelength can reaches up to 300 MHz which is nearly equal to the size of human body. So, the body starts behaving like an antenna and a significant change can be noticed in channel frequency. On the other hand, frequencies less than 100 Khz are always prone to Noise and attenuation [7]. According to Gabriel et al. [1], 100 kHz and 10 MHz is a suitable for human body as permittivity and conductivity of this range is always constant.

- **MAC Protocol design:** BANs are intended to support lifesaving medical applications for remote patients as well, so, safety, security, QoS, and reliability are also considered to be important metrics besides energy efficiency. A robust MAC Layer protocol is always important factor to deal with data transmission in normal and crowded areas. Compromising QOS should never be an option. So, there is a need to develop suitable algorithm for the same. MAC layer protocols should be designed to deal with uncertainties like body movements, posture change and Network node failure. Traffic shaping is also one of the major factors to deal with while designing MAC layer protocols [4]. A simple network setup procedure, self-organizing and self- healing are the essential parameters for convenience of unskilled data/application users [10].

- **QoS and Reliability:** Reliability and QoS are to be treated as most important factor for designing and implementing clinical setting for remote patients as we have to co- op with different natured wireless technologies all the time. The QoS model should be designed in such a way that it can deal with all dynamic configuration requirements along with change adaptability. Fair bandwidth sharing among collocated BANs is highly desirable. BAN devices have limited memory, which means there is always a little room to approach untouched or corrupted data. So, strong error correction, detection and retransmission techniques are to be designed for WBAN [10].

- **Real-Time connectivity over Heterogeneous Networks:** The design of WBAN model should always allow us to connect anytime, anywhere, automatic along with promise of continues connectivity with different infrastructures. There can be several means by which we can connect the whole infrastructure of WBAN like cell phone, PDA or different gateways. For transfer of data we can use various forms of wireless networking infrastructures like WLAN, WPAN or WBAN. This brings forward the need of continues connectivity to heterogeneous kind of networks in WBAN. So, to make WBAN

Design more efficient we have to ensure connectivity for the same in different kind of networking infrastructures.

1.4. Applications of WBAN

The various applications are broadly classified into two sections, i.e., medical and non-medical. The WBAN technology improves the efficiency of physician-patient interactions, i.e., the distant patient medical conditions can be detected and analyzed remotely at any time when any unusual signal is detected. The following describes some potential medical applications and non-medical applications.

- **Remote Healthcare Monitoring**

WBAN can provide automated healthcare services by remotely tracking patient's vital organs. Sensors are strategically installed on/in the patient's body that can send vital physiological signals of the body such as body temperature, heart rate, blood pressure, heart activity monitoring, ECG signal, etc. The movement sensor can be used for monitoring movement of the patient.

- **Providing Assisted Life to Patients**

WBAN also has a fascinating application known as Assisted Living for health and medical facilities. The wearable body sensors can be used at home to measure medical details from the body of the patient and to transmit/store them at regular intervals to specific medical server/control system. This allows the patient to take care of himself at home and receive ongoing support rather than waiting at the hospital. In the event of any serious situation, sensors (embedded on the patient's body) can raise alarm to the nearest emergency department with an immediate warning.

- **Telemedicine**

Telemedicine is another important service provided by WBAN. It provides medical services across a distance with the support of communication and information technology. In the field of telemedicine, WBAN technologies can be implemented, through online video communication with doctors, sharing of medical documents and pictures, online medical diagnosis. The doctor can give online prescription to the patient after tracking the state of health of the patient from almost anywhere.

- **Sports**

The physiological signals such as heart rate, temperature, respiration rate, blood pressure and posture of the any sportsman in sports (wearing WBAN enabling devices) can be examined. These sensing devices can also measure time and distance covered by sports man during navigation

- **Military**

The WBAN plays an important role in military as it may provide communication between soldiers. In a field of battle, troops and the base commander can interact with each other through WBAN to aware about their actions such as striking, walking, fleeing, or digging. The WBAN devices are useful for detecting the status of health, location, temperature, and level of hydration of the soldier in the battleground. To monitor such activities, various types of sensor devices such as camera, Global Positioning System (GPS), tracking sensors, Radio frequency (RF) technology can be mounted on the army uniform. The WBAN can, therefore, provide more precision, protection and communication in any

military campaign.

- **Life Style and Entertainment**

WBAN can have an important role in our everyday lives. It can provide facilities like navigation support while walking, driving, exploring a new location, etc. It can also be used for infant monitoring, support wireless wearable music system, audio/video playback from portable devices to audio system or large screens TV are some examples of WBAN implementations.

2. Literature Review

Some reviews as show in table 2

Authors	Technique/Approach	Findings
Qureshi K.N. et.al (2020)	Energy-aware routing (EAR) by using optimum selection of the next hop	Proposed work performs well in terms of next-hop selection but node mobility is still untouched
Mehmood et.al (2020)	Energy-efficient fault tolerance scheme	Monitoring indicators using cooperative communication to decrease hospital re-admission and thus lower morality rates
Yazdi et.al (2019)	Prioritization of data (from periodic, normal, and emergency)	Prioritization of data traffic reduces the overall delay and energy consumption in WBAN
Kathe et.al (2019)	Thermal aware routing protocol	Routes vital information (i.e., High BP, Low Sugar, etc.) of a patient on a priority basis. mobility of sensor nodes is not considered
Yang et.al (2018)	Hybrid approach of CSMA-CA and TDMA	Performed well in terms of energy but posture change of the human body is not considered
Md. Taslim Arefin et.al (2017)	Highlights the issues and requirements for electronic healthcare system	Suggested fault tolerance and energy efficient system are two main challenges
Ha Ilkyu et.al (2016)	An Even Energy Consumption and Backside Routing	Overhead of the scheme is high due to the selection of forwarding nodes in each round
Jingwei Liu et al. (2014)	certificate less signature (CLS) method	Computationally efficient and proven safe against existential forgery on adaptively selected message attacks.

Shuai et.al (2013)	CAP in Uplink part to deal with the emergency data	Absorbs high energy and it is difficult for the nodes to be precisely aligned to the gateway
Abbasi A.A et.al (2011)	Protocol based on postural mobility	Path discovery activities consumes very high energy
Gengfa Fang et.al (2009)	An energy-efficient MAC protocol	Improved energy efficiency and delay with comparison to IEEE 802.15.4 MAC
Ko, Li-Chun, et.al (2007)	Sleep mode policy using dynamic slot allocation mechanism	reduces overall power consumption and delay. Problem of underutilization of bandwidth still exists

3. Tools and Technologies in WBAN

Simulation Tools: Despite of numerous applications and diverse domain of WBAN, sensor networks face various challenges such as energy limitation, node location, network protection, self- organization, fault tolerance etc. So, there is a big gap for all researchers to work in direction of reliability and fault tolerance. Before deployment of WBAN, rigorous testing of the developed techniques is required. By simulation one can test the performance of the developed model before moving towards real implementation. Large numbers of simulation tools are available for WSN network as on date, some of the popularly used Simulation Tools for WBAN are given below in Table2. During our research work we will use the followings as per requirement.

i) NS-2/NS-3
ii) MATLAB
iii) Jsim/NetSim

MATLAB is a software package by Math Works Inc. used for numerical computation and visualization of high performance, has developed it. Since it combines reliability, versatility, and powerful graphics, MATLAB has become a leading software package for scientific researchers. Its programming capability is the most important aspect of this platform, which is very easy to use and understand, allowing user-developed functions. For special applications such as control systems design, neural networks, signal processing, device recognition, fuzzy logic and others, many optional toolboxes are written. The very efficient Simulink software has improved MATLAB. The technical differentiation between different simulators is shown in Table 2 below.

Table 2: Different Simulation Tools

Name of the Simulator	Programming Language Used	LicenseType	Current Version	Developed By	Official Website
NS-2	C++ and OTCL	Open Source	NS-2 version 2.35/ OTCL Version1.14	DARPA.SAMAN with collaboration of NSF with CONSER and ACIRI	http://www.isi.edu/nsnam/ns/

NS-3	C++ ,Python	Open Source	NS-3.22	NS-3 Consortium	https://www.nsn am.org/
MATLAB	C,C++,Java,Python ,Fortran	Commercial	9.8 R(2020)a	Mathworks Inc.	www.mathwork s.com
Jsim	C, C++, Fortran	Open Source	Jsim 1.3 +Patch4	NSF,DARPA/IPTO, MURI/AFOSR,CISCO, Ohio StateUniversity,	http://j-sim.cs.uiuc.edu/ or https://sites.google.com/site/jsimofficial/
NetSim	C and Java	Commercial	7.2	Developed by Researchers at IRSLab, Jaume-I University, Catellon	http://www.irs.uji.es/uwsi m/

4. Conclusion and Future Scope

Though WBAN is extremely useful in today's scenario, several challenges need to be tackled before its deployment. Through literature study we have identify various challenges that need to be considered before the design and development of any protocol for WBAN. In this research will provide various schemes and protocols used to deal with energy efficiency and fault tolerance.

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