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Wireless Body Sensor Networks: A Review

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Abstract

With the rise in population and increase in older people Wireless Body Sensor Networks can prove to be beneficial in providing medical service to people who require continuous monitoring and care. Development in technologies for Wireless Communication has led to sensor nodes which can be worn over the body, implanted and embedded over the body. These are small sized devices which can perform processing on the signals sensed from the human body and then communicate it to required destination where this data can be used for various research purposes or other diagnosis. In the past much of the research work concerned with Body Area Networks deals with the designing of Sensor nodes, miniaturizing the nodes, various protocols related to communication and routing. This paper gives an overview of Wireless Body Sensor Networks, devices used, its architecture, protocol stack, issues, topology, WBSN standard, challenges. Some protocols and security schemes for Wireless Body Sensor Networks have also been discussed.

Keywords: *Wireless Body Sensor Network, Sensor Nodes, Routing*

1. Introduction

A Wireless Body Sensor Network (WBSN) defines an autonomous system which is used to monitor the daily life activities of a person. It consists of intelligent sensor nodes which do not hamper the daily life activities and are useful in detecting chronic diseases like heart attack, asthma, diabetes etc. and to warn the patients in case of emergency conditions.

These networks offer promising services in various fields such as defense, research, industries, business etc. The sensor nodes in WBSN consume very less power and serve applications in sports training, entertainment, Special Forces (fire fighters, bomb diffusers, military, astronaut monitoring etc.) and consumer electronics. With the help of WBSNs we can monitor activities, movements and vital human body signals from a remote location by the means of internet. Thus it helps in saving money. The demand of these devices is increasing day by day and several aspects like fault assurance, reliability, Quality of Service (QoS) and security need to be fulfilled. Due to changing topology, limited resources such as memory, battery power and varying bandwidth. WBSNs have not been able to fulfill all the above mentioned requirements.

1.1. Types of WBSN

WBSNs can be of three types based on the decision taker of the data collected from various sensor nodes-

Managed WBSN: A Managed Wireless Body Area Sensor Network [1] is a network in which the decision on the data collected from one or more than one Sensor nodes is taken by a third party which can be any doctor, nurse or Medical Centre. The data is collected and sent to the third party where it is analyzed for

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diagnosis. Now the third party will decide as per the data that what has to be done next or what prescription has to be given to the patient. Such network is connected to other networks via WIFI or GSM. The advantage of Managed WBSN lies in the fact that all vital signs can be analyzed and at the same time diagnosis can be done. But there can be problems when the third person we are trying to send information to be too busy to reply or there is some problem with the long range communication. In such cases the patient's situation can go worse.

Autonomous WBSN: The aim of Autonomous body sensor networks [1] is same as Managed WBSNs but they do it differently. In an AWBSN there are actuators along with the sensor nodes that can cause action on the human body as per the data collected from the sensor nodes or by direct interaction with the human body without the need to wait for any third party decisions. An AWBSN works best in case of emergency conditions where decision is taken in real time without any delay and proper action is then taken by the actuator hardware. Here there the Body Control Unit (BCU) is not required to be connected to the external networks. This leads to low transmissions and lower battery wastage. But problems can occur in cases where BCU has not been programmed for detecting a particular disease

Intelligent WBSN: This network is a combination of both the above networks. If situations are simple, decisions are taken on their own by actuator nodes but if they are complex then the information is sent to the third person. If he/she is busy then IWBSN waits for a specific amount of time then takes decisions on its own if there is no reply from the doctor.

1.2. Characteristics of WBSN Sensor Nodes

WBSN nodes have several features that make them suitable for use in large number of emerging applications. Few of them are as under-

Energy Efficient: The nodes are designed in way that they utilize very low energy. Power management schemes are used to handle the power resources optimally so that nodes remain alive for longer time and the network's lifetime increases.

Heterogeneous: Sensors used in WBSNs are heterogeneous in nature each having its own function, some nodes sense the temperature, others sense blood pressure and so on. Each of these sensor nodes has different storage capacity, computation capability and energy consumption.

Cost Effective: Since the nodes use power optimally and are deployed over small area so they live longer and lesser number of nodes are required in network formation and replacement, when damaged. So all this leads to a lower cost of creating a network.

Simple: Lightweight, small sized nodes are used which can be easily carried from one place to the other by wearing them or keeping them in a bag.

1.3. WBSN Advantages

Body Area Networks have proved to be better than the previous approaches so far being used for patient monitoring and in general too.

No wires: The traditional approaches of health monitoring used lots of wires thus making the entire system clumsy. Wireless Body Sensor Networks use small devices which communicate wirelessly with each other.

Energy Efficient And User Friendly: Previous approaches were not efficient in terms of power, mobility etc. but this new approach of using sensors has led to user friendly techniques of tracking the motion, body temperature and other human body signals. We can get the readings on a PDA, laptop anytime we want and can store them for later use too.

Support user mobility: Traditionally the person who used to be monitored had to stay at hospital till they were monitored because of the wires attached to the human body which were in turn connected to the monitor. The patient couldn't move from his bed. But the new technology made patients roam freely, even when they are at home, office and at places far from the hospital, doctors don't have to know their location and can easily access their data on their PC and diagnose them.

2. Hardware Devices

A WBSN consists of tiny devices that perform communication. Mainly there are three types of devices in a WBSN-

2.1. Sensor Nodes

A sensor node performs three mains tasks: signal detection, signal digitization/coding/controlling for communication that involves multiple access and finally transmitting the data through a transceiver wirelessly. The signals that are received from human body are not strong and are accompanied by noise. So firstly the signal strength is increased by signal amplification then the signal filtration is done to remove the noise from it. The Analog to Digital converter converts the analog signals into digital signals which after digitization are stored in the microcontroller.

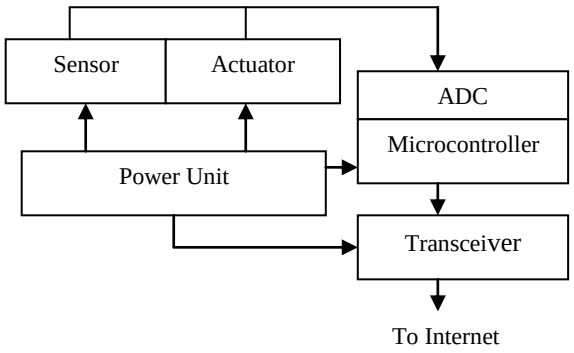

Figure 1. Sensor Node Architecture

At the end microcontroller sends this data in the form of packets through the transceiver to the internet. The microcontroller controls the energy division from the battery in an optimized manner. This is done by the method of power management by switching off the units which are in sleep state.

Commercially Available Sensors

Here we describe few sensors available in the market along with their functions [2].

ECG Sensor

The electrical activity of heart is represented in the form of a graph which is known as ECG and is used for the diagnosis of any heart disease and to see how well are medicines given for heart are working. Electrodes are placed on the human body at places like chest, arms etc. The potential difference between the electrodes gives the ECG signal.

Blood Pressure

This sensor is used for measuring systolic and diastolic blood pressure and makes use of oscillometric technique.

CO2 Gas Sensor

It is used to keep track of the change in the level of Carbon dioxide and to monitor the concentration of oxygen level in blood during respiration.

Humidity and Temperature Sensors

These sensors measure humidity of the surroundings of a person and also his body temperature. If there are some changes in the readings which are above threshold value then alarm signal is issued.

Blood Glucose

Glucose level in blood is measured by extracting blood from a person's finger by pricking it and transferring it on some strip which is made up of glucose sensitive chemicals. Analysis of the collected sample is done by Glucometer which shows numerical reading. But now a days glucose monitoring can be done by optical sensing and infrared technology.

EEG Sensor

This sensor is used for measuring the electrical activity that occurs inside the brain. This is done by placing electrodes at various positions on the scalp of humans. The electrodes sense the information about the electrical activities of the brain and pass it on to an amplifier which then produces tracing patterns. If electrical activities in some regions of the brain are synchronous this means that these regions have some kind of functional relationship.

Pulse Oximetry

This sensor measures the oxygen saturation. For this a clip having a sensor is placed on the finger, toe, earlobe etc. of the person and the sensor produces a signal of light that falls on the skin and passes through it. As per the absorption of light done by oxygenated hemoglobin to the total hemoglobin in the blood flowing through the artery the measurement is made. The measurement is given as the light absorbed by oxygenated hemoglobin upon the total hemoglobin in the artery.

2.2. Actuator Node

The hardware architecture of an actuator node is similar to a sensor node except that it has additional hardware called actuator hardware. For example in case of patient monitoring it has hardware for medicine administration and has an extra socket to hold the medicine. It is useful in case of emergencies when body signals like glucose level in a diabetic patient falls below a threshold value then the insulin can be injected in the body of the human being to save him from death. These nodes perform operation by getting data from the sensor nodes or by interacting with the user and getting data from it directly.

2.3. Personal Devices

These devices are similar to sensor nodes and their task is to collect information which has been collected by the sensor nodes and actuator nodes. After this they pass on this information to the other users over internet through gateways or to the actuators on the body to perform required job or to any external device such as Light Emitting Diode or any screen. These are also known as body control units or sinks.

3. Software

A WBSN requires several kinds of softwares for its proper functioning. Most of the nodes optimize the usage of power by using event-driven software where particular action occurs on the basis of the occurrence of an event. Operating Systems also form part of WBSN software and perform various functions like task scheduling, memory management and power optimization. TinyOS is one of the most used Operating Systems, others being RIOT, LiteOS, ERIKA Enterprise and Contiki. Base stations usually smart phones have Operating Systems like Windows Silverlight, iOS and Android.

4. Architecture

A WBAN consists of small sensor nodes which are heterogeneous in nature. Figure 2. depicts several sensor nodes which are placed over the human body for performing different functions. One used to measure blood pressure, other used to measure ECG, EEG and so on. These nodes are also known as Body Sensor Units (BSUs). These BSUs communicate with each other and perform intra WBSN/tier-1 communication. The data is collected from these sensor nodes and is passed on to one node known as the body control unit. From here the data is sent to other devices or networks, devices can be laptop, mobile phones etc. and is referred as inter WBSN/tier-2 communication. From these devices the data is passed on further to an access point by using existing wireless standards such as Bluetooth, ZigBee etc. From here the data is passed on to the gateway which is used to connect to a wide range of networks. These networks can be hospital networks, telephone networks or a dedicated medical center.

Once the data is sent over internet it is available worldwide. The data at these locations can be stored in the database servers and can be used for analysis by doctors, researchers, used for keeping patient history or for other uses. Some security features can also be applied to make it accessible only to few authenticated persons to avoid its misuse. The information can also be stored on our iPod or mobile phone and then later can be transferred to a Computer. The doctors while sitting far from the patient can diagnose the patient and administer him to get the required drugs. This is known as beyond WBSN/tier-3 communication. We can make use of 3G/4G networks for transferring data over the internet.

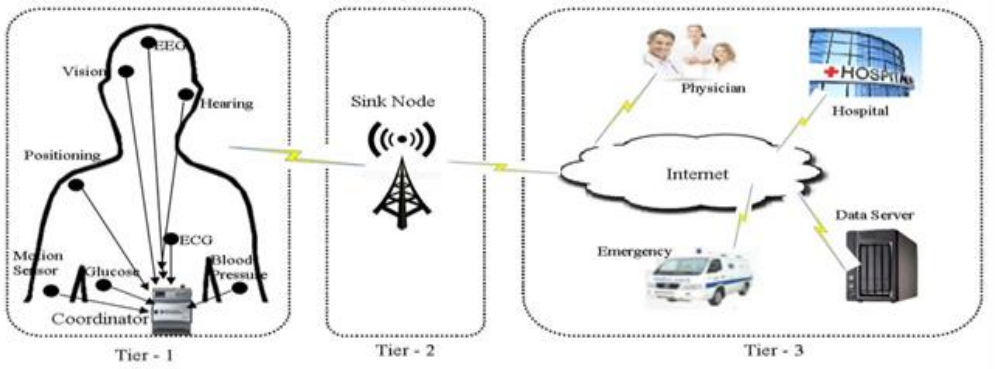

Figure 2. WBSN 3-Tier Architecture [2]

5. Protocol Stack

In WBSN, the communication stack is similar to ISO OSI 7-Layer Model but with fewer layers. It mainly consists of the PHY layer, MAC layer and Network layer. These layers perform several tasks such route discovery, establishment of

links and sharing of communication medium for network formation and nodes' communication and to send data over several routes in an optimized way by performing multi-hop communication. The task of routing and reliable data transfer is done by the network layer. Hardware specifications and channel access are handled by Physical and MAC layer respectively. Besides these there are two other layers: Application-support sub layer and Application Frameworks which deal with applications securing the communication infrastructure and abstraction respectively. Work is still going on the protocol stack for WBSN. IEEE 11073 is working hard to come up with a 7 layer stack solution for communication in WBSNs [3].

6. Topology

Topology refers to the arrangement of sensor nodes in a network. The IEEE 802 Task Group 6 has given approval to a network topology with one hub which is further divided into one hop and two-hop extended star topology. Figure 3. shows the simplest one hub network topology. In one hop topology nodes can communicate directly with the hub and exchange frames. In two-hop extended star topology there is no direct exchange of frames between the hub and the nodes and the frames exchange is done by using a relay-capable node. The hubs and nodes in a WBSN are coordinated with each other based on the arrival time of the packets and the communication occurs through a wireless channel.

Besides these Mesh and hybrid topologies are also the two topologies which are suitable for WBSNs. In mesh topology all nodes can communicate with each other directly whereas the hybrid topology is a combination of different topologies.

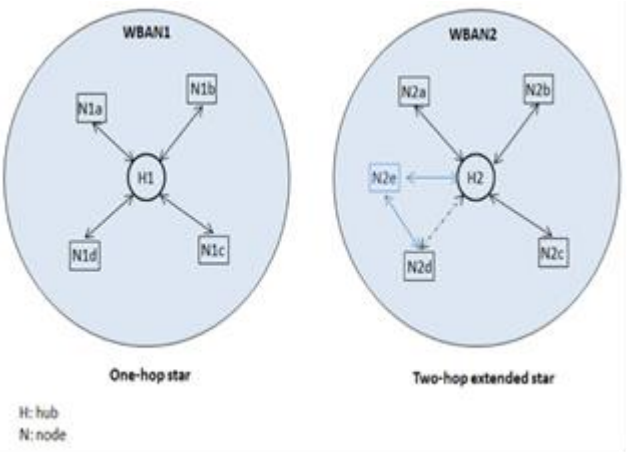

Figure 3. WBSN Star Topologies [4]

7. Issues in WBSN

WBSNs have to face large number of issues. Few of them are described in this section.

7.1. PHY Layer Issues

Band Selection: Applications in a WBSN have different requirements in terms of bandwidth. Applications for healthcare require low data rate. ZigBee is best suited for such applications. For real time applications there is need of low latency which is provided by UWB. So bands should be selected carefully.

Data Rates: Nodes are heterogeneous in nature with each node having its own data rates. So handling of these data rates is also one concern.

Interoperability: Devices in a WBSN operate at different frequencies and have to communicate across different standards like ZigBee, Bluetooth etc. So this can lead to the problem of interoperability. These networks are required to work across different standards without any problem.

Fault Tolerance: Continuous connectivity and fault free communication is required in WBSN which is affected by factors such as disconnections, environment.

Interference: WBSNs have to be near other devices and network. So there are chances of interference of the data signals. It can also be caused by body tissues, heat radiation etc. These networks should communicate without any interruption or loss of data.

7.2. MAC layer Issues

Reliability: It has a direct relation with the probability of loss of packets which is affected by the transmission delay of the packets and the channel's bit error rate.

Control Packets Overhead: The control packets do not transfer data and thus decrease the network's throughput. A lot of energy is wasted by these packets.

Dynamic Channel Assignment: To avoid high delay, loss occurring due to interference and decreased throughput, there is a need of dynamic channel assignment.

Idle listening: This condition arises in two cases- one is when the channel is idle but a node still listens to it and second one is when a node does not receive the packets which it is expected to receive. It leads to more power consumption.

Scheduling: All packets in a WBSN are different. Some packets are required to be delivered urgently while the other ones need to be delivered reliably. So on the basis of the kind of packets flowing across the network a decision has to be taken and a schedule has to be made. This schedule decides which packet will go first and which later.

7.3. Routing Issues

Due to the unique characteristics and distinctive WBSN requirements [5] the development of routing protocols becomes a difficult task. Here are some of the challenges and issues in WBSNs which have to be dealt with while designing routing protocols.

Varying Data Needs: There are different kinds of data in WBSN each with different requirements in terms of quality of service. Some data needs to be delivered urgently while some can be delayed and delivered a bit late. Authors in [6,7] have categorized data of the patients in several types- critical data such as EEG, ECG *etc.*, delay sensitive data like video streaming, reliability-sensitive data such as PH monitor, vital signals monitoring and respiration monitor and ordinary data like heartbeat, temperature, *etc*. Many applications of WSNs like the data-centric applications cannot tolerate loss of packets and latency. The protocols that are to be proposed should be aware of such quality of service requirements for different signals related to the patient's body.

Resource Constraints: WBSNs have low bandwidth, short transmission range, limited storage capabilities and poor computation capability. There may be a change in bandwidth from time to time due to noise and other interferences [8]. Researchers should keep in mind these limited resources while designing routing protocols for WBSNs.

Overheating: The main causes of rise in temperature of a node are the antenna radiation absorption and power consumption of node circuitry [9], which affects

heat sensitive organs of human body [9]. A careful development of routing protocols is required for keeping human tissues safe from overheating due to the above two reasons.

Mobility: Due to human body movements and change in posture the nodes keep getting in and out of range leading to disconnection or network partitioning. Researchers have tried solving these problems in many ways. Maskooki [11] has used Line of Sight and Non Line of Sight communication whereas Quwaider [12] has used the store and forward routing for solving these problems. The proposed routing protocols should keep in mind these topology changes.

Attenuation: Attenuation refers to the decrease in power density of an electromagnetic wave as it travels through the wireless medium. It can also be seen as the power of the transmitted signal to the power of received signal [13]. In case of WBSNs the medium of communication is human body. Path loss exponent in human body is very high and ranges from four to seven [14] whereas the path loss exponent for free space is very low and is two. So the researcher should keep in mind such path loss while proposing routing protocols for WBSNs.

8. IEEE 802.15.6

With the arising need to provide better performance keeping in view the memory constraints, short range communication and energy efficiency etc. a new standard has been proposed by Task Group 6 for WBSNs. This standard is known as IEEE 802.15.6. This section explains why existing standards were not suitable for WBSNs [15] and what makes IEEE 802.15.6 as the best choice for such networks.

8.1. Existing Standards and their Limitations

IEEE802.11, the standard used for Wireless Local Area Networks is mostly used by PCs, computers and pays no attention to the overall network's power consumption. It cannot be used for WBSNs which have energy constraints. IEEE802.15 standards paid attention to short range, less power consumption and meet almost all needs for medical applications but mainly dealt with Wireless Personal Area Networks. IEEE 802.15.4, also known as Zigbee provides long network lifetime and have small data requirements as compared to IEEE 802.15.1(Bluetooth). It has many advantages like small time to join network but still it cannot be a good choice as compared to WBSNs requirements and it doesn't deal with path loss. WBSNs need real time data delivery.

8.2. WBSN Standard and Features

Due to limitations of the existing communication standards, IEEE 802.15.6 came into existence which fulfills almost all WBSN requirements. It performs better in terms of energy efficiency by using sleep mode for a long time. Interference is minimized by using superframes and reliability by using relay nodes.

Security is the main concern in such networks. This standard provides a three level security [16] along with Physical and MAC layer specification.

8.2.1. Security Levels: The security levels are: level 0,level 1 and level 2. Level 0 (Unsecured) is used for unsecured communication. Here transfer of frames takes places in an unsecured way and there is no security checks for message integrity, replay defense, authentication etc. At level 1 (authentication) transmission occurs in authenticated way but is not secured and no checks are done for data integrity. At level 2 (Encryption and authentication) we have the highest level of security where measures for integrity, authenticity, validation etc. are present. The levels are selected as per the application requirement.

8.2.2. PHY and MAC layer features: PHYs can operate at different frequency bands and each has its own properties which are nicely defined by this standard. The PHYs which IEEE 802.15.6 supports are Narrowband (NB) with data rates from 57.5 kbps to 971.4 kbps, Human Body Communication (HB) with data rates from .5 Mbps to 10 Mbps and Ultra Wide Band (UWB) with data rates from 125 kbps to 2 Mbps. This standard provides MAC layer with non-beacon mode with and without superframe boundaries and beacon mode with superframe boundaries. When communication is done using the superframes, the communication channel is divided into superframes or beacon periods. All the superframes are equal in length and consist of allocation slots which are of equal duration. In absence of superframes, a node makes use of CSMA/CA or unscheduled method to access the channel. The hub here can send frames to the nodes at any time.

9. Challenges

Construction of a WBSN needs to take into consideration a large number of things that can lead to network longevity, lesser communication errors and make the network safe and secure to communicate. Following are the factors that have to be taken care of while making a WBSN:

9.1. Energy

It is nearly impossible to replace the battery after short intervals in WBSN especially in case of implanted nodes. So taking care of the power used in the network so as to increase the life of the network is of utmost importance.

9.2. QoS and Reliability

WBSN should be able to transmit error free data that too continuously in real time. Applications of BAN used in medical conditions specially require data to be transferred without any delay and loss. Such critical applications require reliability and QoS as false or corrupted information can lead to serious and even fatal consequences.

9.3. Co-Existence

Data has to be transferred from one network to the other network by using standards such as Zigbee and Bluetooth. So WBSN should be able to operate across different networks without any interference from the other networks in the vicinity.

9.4. Security and Privacy

Depending on the application WBSN can have data which is very crucial and tampering with it can lead to dangerous conditions like death. So there should be proper provisions for performing authorization checks to see whether the user of the information has the right to view the information or not. Integrity of data should also be maintained so that data is not changed at sender and receiver side.

9.5. Data Validation

There can be errors in the information sent over the network due to interference from other networks or due to defective links over the network. This leads to receiving of incorrect data at the receiver side. In case of health applications such data can lead to someone’s death. Hence all the information should be properly validated at the receiver’s side to check for its correctness.

10. Applications

WBSNs serve variety of applications in consumer electronics, healthcare, games and lifestyle [17]. Below we describe some of the WBSN applications:

10.1. Sports and Fitness

In Sports WBSN can be used to examine the health of the athletes. Readings can be taken from the athletes without requiring them to exercise on a treadmill. Coaches can take a closer look at the strong and weak points of an athlete by measuring various body conditions like change in heartbeat, oxygen level etc. during a race and other real life scenarios. This can help in improving their shortcomings and in improving their skills.

10.2. Military

Uses of WBSN in defense are many. Examining the health condition of soldiers, checking level of hydration, tracking their location and body temperature monitoring are few of them. All the readings can be used for providing help to the soldiers when they get injured, to get an idea of when strength, precision, attention have to be enhanced and can also be used for reducing incidents of friendly fire due to misunderstanding in identity by telling them their exact location and identity time to time.

10.3. Emergency Services

WBSN can be used in providing emergency services to fire fighters. The readings of changes in body conditions of fire fighters like oxygen level, pulse etc. is taken and along with it the toxin level in the air are monitored and the fire fighters are warned in case of the emergency conditions or asked to leave the location or use some preventive measures like using gas mask.

10.4. Emotion Detection

Human emotions can also be monitored by WBSN. A chemical called serotonin is created in the human body by the brain and the intestine. Decrease in level of serotonin causes sadness and increased level causes happiness or anxiety. Thus we can keep track of this chemical and know the mood of the person.

10.5. Personal Health Monitoring

Non-stop monitoring of critical parameters of the patients who suffer from chronic diseases such as heart attacks, asthma and diabetes can be done by WBSN. Readings of ECG, EMG can be taken by patients on their own at home and can be checked by doctors.

10.6. Posture Detection

The posture of a person can be detected by using sensor nodes. Games can be played on computer by wearing sensors over body that gives a feel as if a person is playing on a real field. The motion of the player changes as per player's motion. Dance lessons can also be given by gesture detection and body movement.

10.7. Medical

BANs can prove to very helpful in monitoring the health of the patients from faraway places. The patient and doctor do not necessarily have to be at the hospital.

Even when patients are at home they can be administered medicines and their body's vital signs like blood glucose level, heartbeat, blood pressure etc. can be checked. In the near future the patient would be monitored independent of their location and required drugs can be prescribed to them. There will not be a need for patients to remain connected to big machines for getting monitored.

10.8. Consumer Electronics

Devices like microphone, MP3 players and head mounted displays can form a part of BAN and play their respective roles. Like as per the mood of the person songs can be played etc.

11. Protocols

Protocols refer to set of communication rules in a network. This section gives a brief description of MAC and routing protocols used in WBSN. Below are some of the protocols:

11.1. MAC Protocols

All nodes in WBSN share the same channel for communication and data transmission. The task of controlling the channel access to the nodes in WBSN is performed by MAC. Below are some of the MAC protocols for WBSN:

Controlling Access with Distributed slot Assignment (CICADA) [18]: It uses a tree structure for providing collision free medium access and for routing the data from source to the sink. It offers low delay and can be used for multi-hop WBSNs which are mobile in nature. Energy consumption is also less as the nodes can go in sleep mode when they don't have to transmit or receive any data.

BSN–MAC [19]: BSN-MAC is a feedback-based protocol which consumes very low power and provides energy critical nodes with low latency. It does this by adjusting IEEE 802.15.4 superframe parameters dynamically by taking feedback from all the distributed sensors present in the network. It is compatible to IEEE 802.15.4.

Heartbeat Driven MAC (H-MAC) [20]: It is an energy efficient protocol which does time synchronization by making use of the rhythm of human heart beat. Due to this sensors can be synchronized with each other and there is no need to gather information from the coordinator node from time to time. Thus it leads to less communication and more energy saving

.

11.2. Routing Protocols

Bangash *et al.*, [21] has divided the routing protocols into several categories. Here we give a brief overview of the existing routing protocols-

Temperature-Aware Routing Protocols: There are several reasons for rise in temperature on human body such as power consumption by the node's circuitry (Tang et al., 2005), antenna radiation absorption. This can damage human tissues in the long run. Temperature aware routing protocols have been developed to reduce the rise in temperature in sensors. Routing Algorithm for Network of Homogeneous and ID-Less Bio-Medical Sensor Nodes (RAIN) [22], Thermal-Aware Shortest Hop Routing (TSHR) [23] decrease rise in temperature and reduce packet delay hence providing better packet delivery ratio.

Qos–Aware Routing Protocols: Based on QoS metrics these protocols use different kinds of modules and perform communication between these modules and hence are module based protocols. QoS-Aware Peering Routing for Delay-Sensitive Data (QPRD) [24] provides less delay, QoS-Aware Peering Routing for Reliability-

Sensitive Data (QPRR) [25] improves reliability. Both are better in lowering energy consumption.

Postural-Movement-Based Routing Protocols*:* WBSNs topology suffers from problems like partitioning. These protocols try to solve the problem of disconnections which are caused by human body movements by using a cost function. The data is forwarded over the path with the minimum cost from source to the sink. On-Body Store and Flood Routing (OBSFR) [26] reduces packet delivery delay, Probabilistic Routing (PRPLC) [27] reduces end to end delay.

Cluster Based Routing Protocols: Here the sensor nodes are divided into clusters and methods are used for selecting a cluster head out of all these nodes. Data is send via this cluster to the sink node to reduce the number of direct communications between the individual nodes and the sink node. Hybrid Indirect Transmission (HIT) [29] and Anybody [30] improve packet delivery ratio and energy consumption. Anybody decreases latency and improves packet delivery ratio too.

Cross-Layered Routing Protocols: These protocols have come up with the aim to provide solution to the issues and challenges faced by network and MAC layer together at the same time. Thus improves the overall network performance. Wireless Autonomous Spanning Tree Protocol (WASP) [31] energy consumption and end to end delay, Timezone Coordinated Sleeping Scheduling (TICOSS) [32] reduces packet delivery delay and and Biocomm [33] reduces packet loss and increase network throughput. These are the few protocols that come under this category.

12. Security Schemes

Data in a WBSN is crucial; any changes to it can prove to be fatal. WBSNs have to be secured against various attacks like eavesdropping, tampering, DOS attacks etc. Below are two types of security schemes for WBSNs:

12.1. Private Key Cryptography Based Security Schemes

Here the task of encryption and decryption is performed by a single key which is known as the secret key.

Sampangi et al. [34] has proposed a new security scheme for WBSN which makes use of Independent and Adaptive Key Management (IAM) and Key Management Scheme for security in Inter Sensor communication (KEMESIS). The keys are generated in a random fashion which perform the task of encryption and decryption both at the sender side as well at the receiver's side independently. Key exchange or distribution is not required between the sensors. The keys can be provided to corresponding sensors before the actual deployment of the nodes. But this scheme is not good as it proves to be inflexible. Keys can also be circulated by using other methods like bio channels such as Inter Pulse Interval (IPI). Poon et al. [35] has proposed a biometric approach for authentication and key distribution in WBSNs which makes use of IPI as the biometric feature. At the sender's end IPI is used for sending the key and the receiver on the other end captures own copy of IPI and use it for getting the key. IPI can be obtained from signals like heart rate, ECG whose readings can be taken from places like chest, lower limbs etc. This scheme takes care of the Integrity, authenticity and confidentiality of the data. Plethysmogram (PPG) based security scheme has been proposed in [36] makes use of one common key for the entire WBSN. The sensors wishing to communicate with each other in a secure fashion do the PPG signal measurement for some amount of time which is predefined. One sensor among the two communicating ones performs arbitrary key generation. The PPG signal is used for hiding the generated key. This key is passed on to other nodes which unhide the key in their own ways. Main aim of PPG based

key Agreement is to use PPG signal and get one symmetric key which is common for all.

12.2. Public Key Cryptography Based Security Schemes

In such type of protocols we have two kinds of keys- private key and public key. Private key is the secret key which is known only to some particular sensors while the public key is known to every sensor present in the network. The public key is used to perform encryption while they private key performs decryption. Therefore there is no need to send the keys in a secure fashion.

A protocol for strong authentication has been proposed in [37]. It presents a three elliptic curve based key agreement protocol with authentication via hidden public key transfer, pre-shared password and with only fractional variations from a common unauthentication based protocol. Author in [38] proposes a secure and efficient data storage scheme which does integrity checks in WBSN dynamically and provides data confidentiality while storing and accessing the patient's data. Only users who have authorization can access the stored data. A certificateless remote anonymous authentication protocol [39] is proposed by which no one can disclose the information related to the patient, not even doctors. It uses anonymous account rather than using the patient's actual identity. It makes use of Certificateless Public key cryptography (CL-PKC). Only part of the key is generated hence the network cannot impersonate the client.

13. Conclusion

BAN provides useful applications in healthcare, entertainment and fitness. It can prove to be a revolutionizing technology in the next few years whose applications will not be limited to the areas mentioned in the paper but will come up with more new possible applications and will provide more market opportunities to developers. Though works are being done in solving the various issues like latency, interference, dynamic topology, works should also be done to make this technology more user friendly and convenient to users thus enhancing their general comfort. Sports and entertainment are taking new directions and new opportunities will be available for people working in this direction. At present the amount of information that can be transferred over the WBSN is limited and the resources to supplement power to the nodes' battery are not much, but in near future WBSN will show a tremendous improvement.

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