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Survey on Energy Efficiency Protocolsin Wireless Body Area Networks (WBANs).

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ABSTRACT

Nowadays, Wireless Sensor Networks(WSNs) becomes a very hot research area and interested by many of the scholars due to its high impacts in different areas of its application. One among the most important domain is in Wireless Body Area Network (WBAN). WBAN is a technology that makes use of sensor devices connected wirelessly to monitor the health condition of a patient all the time. Since they are wirelessly connected and moves from one place to another due to the mobility of patient, these devices need a lot of power in order to operate for a long time. Energy conservation is a major challenging problem that someone must take into consideration while designing these devices. This paper presents a study survey of different protocols available in nowadays that are used to implement such the operation of these devices in order to survive for a long time while they conserve the power they are using.

Keywords: Wireless Area Networks, Sensor, Energy efficiency, Energy conservation

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INTRODUCTION

Utilization of wireless body area networks is the most promising approach in building the wearable monitoring devices for health care domain. Wireless Body Area Networks (WBAN) also known as Wireless Sensors and Actuator Networks (WSAN), is a technology that uses wireless sensor nodes in the real-time devices for health monitoring purposes[1]–[3] This wearables can be implanted inside the body or can be worn externally. In simple terms, this network connects independent nodes that area situated in the clothes, on or under the skin and is distributed all over the human body. This gives the complete health details of a patient even in mobility, since the sensor devices are capable of processing and communicating with vital signs such as blood pressure, heart rate, temperature, humidity and other environmental parameters. The sensor devices are connected through a wireless communication channel in any means of topology, but mostly these nodes are connected in a multi-hop or star topology [4].

WBANs have great possibilitieswhen it comes to applying its usage in the medical field where the focus is on prevention or early detection of disease. There are other several applications such as remote medical diagnosis, interactive gaming, and even for defense military purposes such as surveying soldiers fatigue, weariness, battle readiness etc. WBANs application is basically of two kind, in-body and on-body applications [5]. Program transforms for pacemakers, limb movement restoration, monitoring, maintaining and controlling of bladder function, and implantablecardiac defibrillators are part of in-body applications.On-body usage of WBANs include heart rate monitoring, temperature, blood pressure and control of respiration. Other non-medical applications of on-body includes building a social network and monitoring forgotten things are few examples.

To achieve good construction of the WBSN, there are some important features, requirement and protocols thatare required in orderto guarantee the effective operations of these devices, Bulger et al in [6] mention some of them which includes:-

- Any WBAN should able to provide a wide range of supporting that to be conducted in in medical applications such as getting testing data from sources and sending the information to the service device within a short time of postponement and avoid of misplacing of critical data and information.
- Again, the WSAN should be able to function in the environment with less power in such a way that, the power source such as batteries must function efficiently for a long time.
- Another requirement is that, the WSBN should be self-restorative, protected and trustworthy.
- The data rates going from 10 Kbps to 10 Mbps should be supported by any WBAN so that it can hold many medical applications data such as video, images and sounds.
- Moreover, a WASN must provide features for quality of services management for provisional of urgency services. Mainly during monitoring process, the application should assure sending and supply of critical information to the service device where the medical data of the patient are gathered and deposited for other investigations. In the case of medical data, the main quality of services features is sending delay and missing data by loss.
- Other requirement, a WBAN must function as well as co exists together with another node that are function in the same group of frequency bands.
- A WBAN should also able to function in a various and a mixed network environment, the environment where many different standards may work together and collaborate with each of them to collect and gather data received from sensors.

As Wireless Body Area Network, being the part of Wireless Sensor Network (WSN) it inherited some demerits such distributed networks struggling with. One of the major setback when it comes to wireless networks is the energy efficiency management[7].

The thought of energy preservations indesigning and implementation of Wireless Sensor Network is not a new issue and will be in research concern for many years to come. Since the WSN nodes use powered batteries, these batteries has limited lifetime capacity and the major requirement of wireless sensor devices is energy

efficiency[8]. Therefore, successfully controlling and managing of energy savings will brings about these nodes (devices) to operate for a long time, the situation that will enable the data and information to be collected from a patient in efficient way.To archive such success, different researchers tries to work out on different protocols and techniques to deals with this situation with the aim of increasing the energy lifetime for these devices. This paper presents a survey of different protocols existing for energy efficiency and maintenance for a successful implementation of WBANs. The rest of the paper organized as follows: - Section 2 present related works. The WBAN architecture is described in details in Section 3. Section 4 provide some challenges facing the implementation of WBAN. Section 5 present a survey of different protocols available as a solution to deals with energy efficiency problem. And inSection 6, the paperfinalizes with a conclusion.

RELATED WORKS

Many studies related WBAN energy conservations presented in different conference and published in different journals to explain different means, techniques and protocols to follow in order to overcome the problem. In study [9], the authors proposed an algorithm known as Centralized Immune-Voronoi deployment Algorithm (CIVA). This algorithm aims to maximize the power lifetimeof a particular node as well as to enable the Mobile Sensor Node to sense in a wide range in terms of coverage. A pre-scheduled wakeup radio which depends on MAC protocol for sensitive and periodic data was proposed in[10], the techniques used was CSMA/CA in which the priorities were allotted to sensor nodes while regulating their size and data types. For the purpose of energy maintenance, a mechanism that used a radio-wakeup used to manage the live and sleep of sensor nodes. Mathematical calculations also derived to examine and investigate the performance of energy feeding, amount given out, possibility of losing of data packets and average interruption of the data that cause some delay in transmission for critical and emergency data. Moreover, authors in [2] propose a new technique known as Gateway Selection Algorithm (GSA). The GSA algorithm influences in the usage of energy gathering technologies and vigorously choose the most appropriate WBAN node that works as an entrance to other wireless networks. The aim of the study is to give ability to the nodes to stabilize the capacity between the sensor nodes by automatically changing the entrance node in Wireless Body Area Network subject to the energy backup of the nodes. An application designed to improve the energy consumption of different arrangements of devices was presented in study [4], this application makes use of the two dipoles that were positioned immediate to the patient body, the dissemination of the channel were measured in the patient body using different ways, and in different areas of the patient body separately. The paths damages were also examined and automatically were corrected by using special model which is known as 3-D electromagnetic solver.

WBAN ARCHITECTURE

The framework comprises of multiple sensor nodes that monitor movement of the human body, heart and pulse activities, a system network coordinator, and a server running on a personal computer alternatively for individual check. The main functions of the sensor nodes are to notice the unresponsive sample vital signals and transfer important and appropriate data to server through wireless network such as ZigBee or Bluetooth. The server, further sends the data on to the doctor's personal digital assistant (PDA), cell phone, or normal computer and the response, the interaction between patient and doctor, the information concerning the health situation will be transferred to the medical server through the Internet or mobile telephone networks using GPRS, 3G, etc[11]. Important information gathered by the medical sensors from body is transmitted to the data collector asshown in **Figure 1** below. The sensors are activate all the time and continuously monitor, and transfer the data to the collector.

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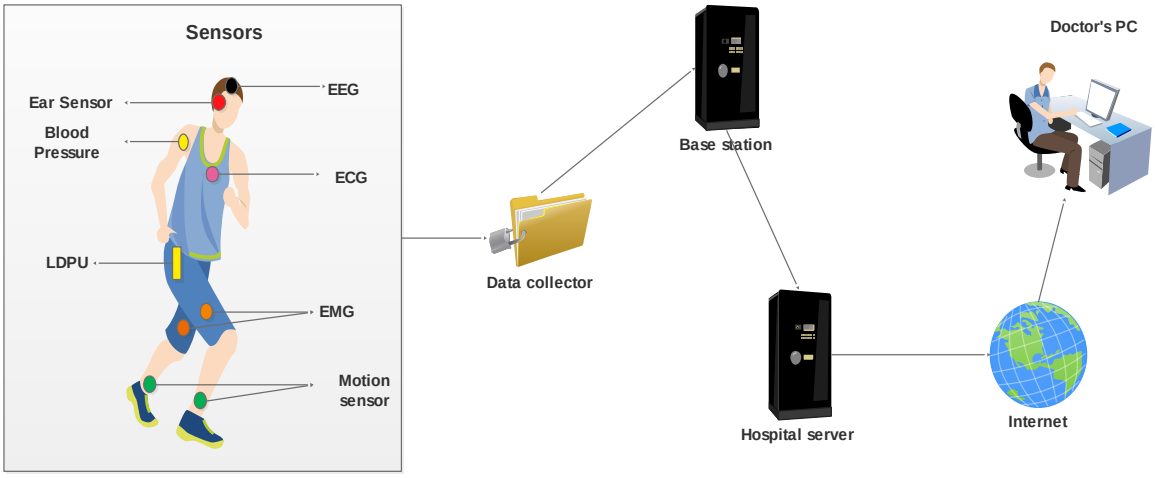

Figure 1 - WBAN Architecture

The architecture shown in **Figure 1** abovedescribes several keycomponents. Types of medical sensors which can be used for monitoring various parameters of human, whereas **Figure 2**,represents another form of WBAN in different form. The relevant data collected fromdifferent nodes are sentto different clients, doctors or health care centersthrough the internet.The medical/hospital server retains medical records of users and patients which provides various useful details to the doctors, medical personnel or informal caregivers. It is important to verify the authentication of the users of the hospital server before letting the user use the information from the server.

Accepting health monitoring session uploads, plan and enter these collected data into corresponding medical records, analyzing the data patterns, recognizing serious health anomalies in order to contact emergency care, forwarding or initiating new instructions or treatment to the users, these are few examples of the medical records stored in the hospital/medical server. This system allows the patient's doctor to access the useful data of the patient from the office through the Internetand conduct tests to ensure the patient is inside anticipated health measurements (e.g. heart rate, blood pressure), confirming that the patient is responding to the ongoing treatment[12]

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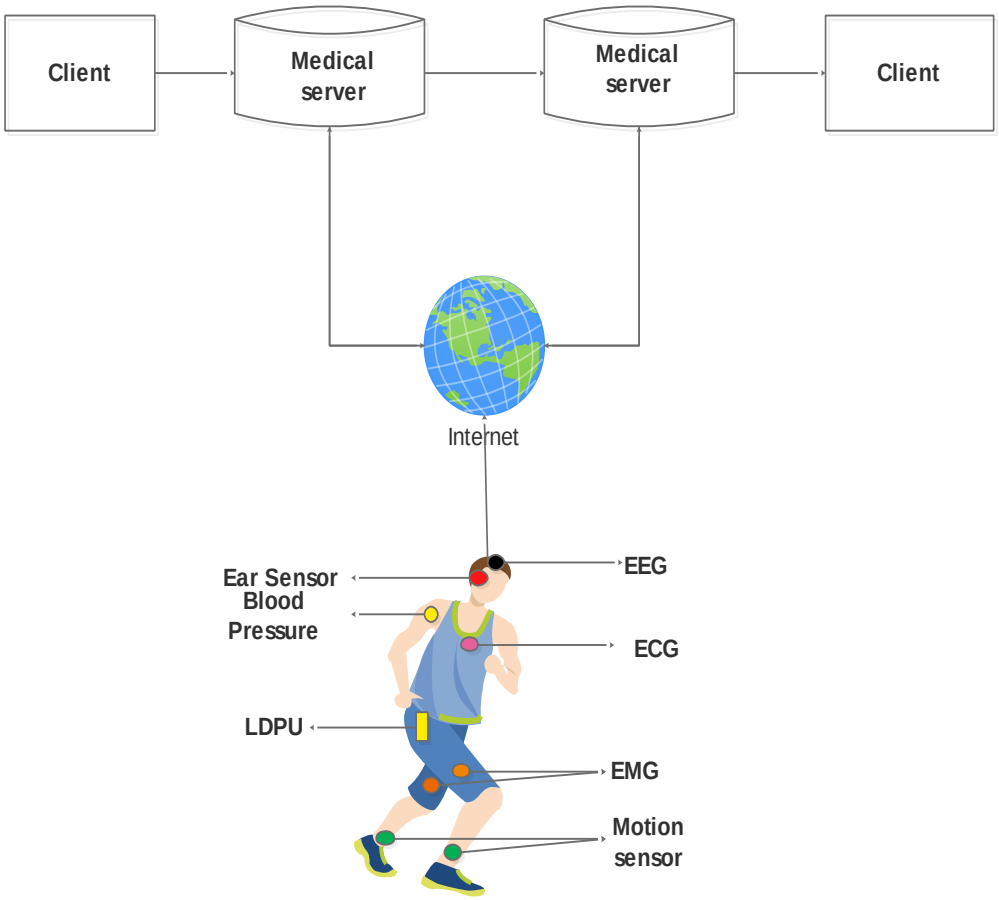

Figure 2–Another form of WBAN Architecture

CHALLENGES FACING IMPLIMENTATION OF WBAN

In the designing implementation of communication protocols for the wireless body area network (WBAN), there are number of challenging that facing these process, these includes interoperability, scalability, reliability, Quality of Service, security and energy efficiency. Reliability and energy efficiency are two key performance metrics in WBAN [13].

Interoperability

In the field of health care, the term interoperability can be defined as the competence of the technology to connect, exchange data and use the obtained data for medical reasons. The data obtained from the sensor can be stored in a local server, upload the data for medical purposes and also to remotely access the data[14]. Additionally, the device must be of ease of use since the patient can reconfigure the device at the physical level to accommodate different monitoring requests, such as system assembly and disassembly, sensor removal, sensor addition and operational mode.

Quality of Service

Quality of Service (QoS) is another part which is most important in the context of risk management of medical application[15]. The necessity of QoS is to reduce the delay and while increasing the probability of successful and better transmission of packets of data[16].

Reliability

The main concern in reliability is data transmitted from the sensor to be received correctly.Reliability depends on what type of device used, how the data is transmitted, how the integrity, confidentiality, availability and dependability of the data is ensured. Some of the risks that required to be considered in order for reliable data transmission, these includes resource limitation, unpredictable traffic patterns, unsteadiness of network, network dynamics, energy stability, data dismissal, heterogeneous traffic types, packet criticality, unbalanced traffic and multiple collection point [17].

Security

The health-related information sharedbetween sensors devices in a WBAN and transmitted to the server via the communication network areseverely private as well as confidential and thus they must be encoded to keep the patient's privacy. Data integrity and repudiation must be maintained on the data obtained from the patient. The patient or employee handling the security related technique should be aware of how to carry them out. The network mustnot be reachable whenever the user is not capable to give the password (example to guarantee accessibility by paramedics in trauma or other emergency situation) [15]. With respect to data storage, a secure WBAN should ensure confidentiality, integrity, availability, and dependability while with respect to data access; it should provide services like privacy, non-repudiation, revocation, and accountability [17].

Energy Efficiency

Energy efficiency is the most key challenge to be that hinder the implementation of WBAN. Using energy efficient communication protocol to maximize the network lifetime is important in WBAN application this is due to its limitation of power supply in the sensor devices which use batteries [18]. The basic way of saving power is to diminish the energy wastage. There are number of reasons which brings about the wastage of energy, these includespacket collision, over hearing and idle listening[16]. By designing efficient protocols, this energy wastage can be controlled. The most and basic factors to consider while designing energy efficiency protocols includes collision avoidance, latency minimization, high output and reliable communication. Minimizing sensing data processing and communication will lead to energy depletion and hence energy efficiency can be achievedalso [16]. Various approaches are adopted for the energy saving mechanism in different protocols such as Low power listening (LPL), Scheduled contention and TDMA. In this paper, we compare different protocols that are used to guarantee the efficiency usage of energy in WBANs.

ENERGY EFFICIENCY PROTOCOLS

Ideally, we want the sensor to organize with its performance, the purpose concerning is to illustrate long life. The scheme would be energy efficient when it is statistically optimal and causal. The most practical problem which one does not want to deal while surveillance or monitoring applications is gaps and breaks to develop. Therefore, defining the lifetime as to maximize and the crucial scenario. In this section we will discuss two main protocols that are used. These protocols are

(i) MAC Protocol
(ii) Routing Protocol.

MAC PROTOCOLS

MAC protocols is the most used protocol used to guarantee the energy efficiency of the designed WBANs. In order to expand the efficiency of energy, a MAC protocol should offer enough capability of reducing the energy consumption. Different MAC protocols proposed by different studies, these include S-MAC, T-MAC, ZigBee and Baseline MAC Protocols. In this section, we present different MAC protocols for energy efficiency purpose, and the comparison between these protocols are also described.

S-MAC (Sensor MAC)

S-MAC uses sensor network to communicate between peers to improve energy sensor node. In this protocol, periodic listen and sleep mechanism is used to achieve low responsibility cycle operation for every sensor device. Each device sleeps for a given time period and then wakes up to check if there is any communication to be done or not. In sleep mode, the radio is totallytwisted off and a regulatoris adjusted to awake the sensor device at a later time. The sensors try to adopt same sleep schedules of each other, rather than sleeping and waking up on their own. The complete listen and sleep state is called a frame [16]. The listen frame is separated into several intervals for sending, receiving, SYN etc and the duration of the listen is set to be fixed depending on the physical and MAC layer parameters.

MedMAC

MedMAC is derived from a TDMA protocol, the protocol comprises of two structures for the aims of energy conservation, namely Adaptive Band Algorithm and Drift Adjustment Factor. The two structures are aims to provide synchronization between the coordinate node and the remaining nodes.[16] The synchronization process taking place in the presence of Guard band which make the nodes to snooze for a different time period. The drift Adjustment factor is introduced for the purpose of reduce the bandwidth. This protocol seems to reduce the collision and hence the energy is conserved

T-MAC (Time-Out MAC)

T-MAC is improved version of S-MAC Protocol where it uses dynamic duty cycle instead of low duty cycle of S-MAC. It regulates the length of an active period by simply timing out if nothing is heard from each node periodically and wakes up to communicate with its neighbors and then go to sleep until the next frame. Idle listening time has improved but has the same energy efficiency as S-MAC protocol.

DTDMA

Reservation based dynamic TDMA protocol makes use of slotted Aloha in CAP field of super frame to reduce collision and power efficiency [16]. In this protocol there is reduced packet dropping rate and less consumption of energy while on the other hand, it does not support emergency and on-demand traffic. As the overhead increases due to synchronization between nodes and coordinator is required in TDMA which results in energy efficiency trade-off.

Okundu MAC

Okundu is one of the energy efficient MAC protocol for single hop WBAN which consists of three processes namely link establishment, wake up service and alarm process [16]. It reduces time slot collision, idle hearing and over hearing while the only disadvantage is that it can only connect to not more than 8 nodes. As the number of slave nodes increases, the scalability of the network decreases.

Ta-MAC (Traffic aware MAC)

Traffic aware MAC protocol utilizes traffic information to enable low power communication [16]. It can be used in normal, emergency and on-demand traffic and also is energy efficient with reasonable delays while it is not suitable for dynamic topologies. Central coordination is required to control the traffic in this network. To gain energy efficiency, the transfer rates are reduced or delayed due to node overheads.

H-MAC (Heartbeat Driven – MAC)

This protocol makes use of heart beat pulse information for the purpose of synchronizing the nodes. In this protocol, the energy consumption is minimized in large amount since it avoids to use the outside clock for synchronization process. The protocol also avoid collisions since each node is allocated each own slot to use. The purpose of H-MAC is to minimizes the cost of energy as well as improves the Wireless Body Sensor Networks energy productivity.

Low Duty MAC

In low duty cycle MAC, all the complex tasks are done by the master node while simple tasks like analog to digital conversions are done by the slave node. In this protocol, collision problems are reduced while this protocol cannot be used in dynamic type of network. This makes use of guard time and TDMA to achieve energy efficiency [16]. To reduce the packet loss ratio, extra slot in the time frame are used which is the only trade-off of this protocol.

ZigBee MAC

ZigBee can use two schemes CSMA/CA, where it gives only average performance, and TDMA, where power consumption is reduced vastly [19]. Its best to use when there's less number of nodes and the network traffic is less. This is one the best protocol for energy consumption.

The table below shows the comparisons of different MAC protocols discussed above

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Protocol	Used technique	Energy efficiency	Advantages	Disadvantages
S – MAC	Mainly depends on slots and operational arrangement	Good	The overhead can be reduced due to long inactivity and synchronization time caused by snoozing of nodes	Can result to low output, if packets are not reach to the intended node, over listen and collision may be occurred.
MedMAC	It makes use of Drift Adjustment Factor, Time Division Multiple Access and Adaptive Guard Band.	Very good	Energy consumption due to collision is reduced for large extent	It is limited for application with high data rate
T – MAC	Mainly depends on slots and operational arrangement	Good	The packets are transmitted in the form of eruption; this improve the result under different number of nodes	It is suffered from snoozing problem
DTDMA	It depends on Time Division Multiple Access and the uses of positioned ALOHA	Good	Fewer energy consumption and also the rate of dropping packet is diminished	It is limited for real time application that required an emergency and on-demand packet traffic
Okundu MAC	It makes use of Wake-Up and fall back time	Good	The time slot collision, overhearing and idle listening all are reduced for high extent	It is limited with only 8 nodes that can communicate
Ta-MAC	It works in a centralized management depending on the traffic form of the nodes	Very Good	It fit for any kind of application such as default, on-demand packet traffic and emergency applications. It also has good and well-organized energy management and realistic delay	It is limited for application with dynamic topology
H - MAC	It makes use of synchronization, in which a Heartbeat Rhythm information is used for that purpose	Good	It minimizes the cost of energy as well as improves the Wireless Body Sensor Networks energy productivity	It is limited in supporting periodic events as well as it has less bandwidth efficiency
Low Duty MAC	It uses Time Division Multiple Access together with the theory of Guard Time	Good	It minimizes the problem of packets collision in high extent	It is limited for dynamic topology applications.
ZegBee MAC	It makes use of small network and follow both CSMA and TDMA	Good	It gives an average performance as well as it reduces the energy consumption immensely.	It has some limitation, since Its best to use when there is less number of nodes and less network traffic.

Table 1 - Energy Efficiency MAC protocols

ROUTING PROTOCOLS

Ideally, we want the sensor to organize with its performance, the purpose concerning is to illustrate long life. The scheme would be energy efficient when it is statistically optimal and causal. The most practical problem which one does not want to deal while surveillance or monitoring applications is gaps and breaks to develop. Therefore, defining the lifetime as to maximize and the crucial scenario. In this section we will discuss few of the energy efficient routing protocols. All the routing protocols are classified based on particulars such as data centric, location, architecture requirement, application needs etc. The below mentioned protocols take clustering approach for developing routing protocols for WSN.

Equalized Cluster Head Election Routing – ECHERP

This protocol- ECHERP utilizes the Gaussian Elimination algorithm to find the solution after having done the head selection process [20]. In the network the energy conservation takes place through balancing the cluster. The transfer of the fused data to the base station is done using the multi-hop routing scheme. Therefore, ECHERP achieves substantial energy efficiency. The process of Gaussian elimination is carried out in two phases. First phase, uses the forward elimination technique, representing the energy spent, which is reduced through elementary row operations. In the second phase, back substitution technique for finding solution to the above system.

Low Energy Adaptive Clustering Hierarchy -LEACH

Low Energy Adaptive Clustering Hierarchy is a time division multiple access protocol along with clustering. This hierarchical protocol presents most nodes transmitting to cluster heads. LEACH uses the single hop routing and transmits the information from each node directly to the cluster head. The operation consists of two phase[20]. The setup phase and the Steady state phase. Organizing of the cluster and the selection of the cluster heads is done by applying stochastic algorithm on each node to determine cluster head in the setup phase. In the steady state phase, data is sent to the base station. To minimize the control overhead, the duration of the second phase is longer than that of the setup phase. However, this protocol isn't suggested for large regions.

Power-efficient Gathering in Sensor Information Systems - PEGASIS

An improvement of the LEACH protocol is PEGASIS [21]. The communication takes place only with the nearby neighbor for the exchange of the data and each node takes turn to transmit the information to the base station, thus reducing the energy utilized per round. The starting node of the formation (chain structure) is selected using the Greedy algorithm and each node takes turns to be the head for the transmission to the base station. PEGASIS, however doesn't take base station's location nor residual energy of the nodes into consideration for the selection of the cluster head. Experiments have shown that PEGASIS outperform LEACH protocol[20], [21].

Threshold Sensitive Energy Efficient - TEEN

Threshold Sensitive Energy Efficient is a hierarchical protocol with the network architecture of hierarchical grouping. This routing protocol is designed for the sudden changes seen in the sensed attributes or environment such as temperature. The protocol response for the applications in the network associated with time crucial is important, forcing the network to perform in the reactive state. The procedure is that in the hierarchy, the nodes close to upper hierarchy are used to transfer data from the ones that are far from them and it continues until it reaches the base station, also called as sink. TEEN routing protocol operates excellent in conditions where sudden changes occur in the sensed network. However, threshold protocol tends to consume more amount of energy in the large area network where the number in the hierarchy level is small, as it takes long path to transmit information to the base station. More the number of layers, shorter the transmissions becomes resulting in considerable overhead in both setup phase and operation of the network[20], [22].

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Stable Increased Through-put Multi-Hop Protocol for Link Efficiency - SIMPLE

Stable Increased Through-put Multi-Hop Protocol for Link Efficiency is one of the reliable protocol that gives stability in the system and consumes less energy due to multi-hop communication. The procedure is carried out using the cost function he selection of node heads and the relay nodes. The relationship between distances from their base station to the residual energy of the node is defined as the cost function [23], [24]. The nodes with the less cost function are selected as the head node (or) parent node and rest are called relay (or) children nodes. The data from the relay node is transmitted to the parent node and further to the base station. It's not necessary that the nodes deplete energy while forwarding the information of other nodes. Hence this enhances the network stability and results in long life of the system.

Protocol	Mechanism	Energy efficiency	Algorithm used	Advantages	Disadvantages
ECHERP	Clustering of nodes only once.	High	Gaussian Elimination	Uses multi- hop routing	Control Overhead
LEACH	Clustering of Nodes	Low compared to another four protocols	Stochastic Algorithm	Dynamic clustering results in longer lifetime of system	Unbalanced energy level reserves in nodes & overhead
PEGASIS	Clustering of Nodes	High	Greedy Algorithm	Eliminates overhead of dynamic cluster formation	Chain formation causes redundant data transmission
TEEN	Data Centric	High	Hierarchical grouping	Reacts to time critical events	Not suggested for applications where periodic reports are needed
SIMPLE	Multi- hop communication	High	Cost Function	High throughput, stability and longer lifetime of system	Rarely path loss

Table 2 - Routing protocols for Energy efficiency

CONCLUSION

Energy efficiency is a fundamental factor when dealing with Wireless Sensor Networks, particularly for the implementation of WBANs, whereby sensor devices required to be active and functioning all the time internal within a patient's body or external in the forms of wearable devices. Due to non-stop operations of these devices, energy consumption becomes to be a big challenge that faces designing processof sensor nodes. In this paper, we present a survey of energy efficient protocolswhich are MAC and Routing protocols. In these two categories, different proposed protocols that belongs tothem were discussed. The paper compares those sub-protocols in different parameters such as mechanism used to design the protocols, the amount of energy efficient it possesses and some advantages and disadvantages they have.

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