ADAPTIVE MAC PROTOCOL DESIGN FOR ENERGY EFFICIENT AND RELIABLE WBAN LINK

A Thesis submitted in partial fulfillment of the Requirements for the degree of

Master of technology
In
Electrical Engineering
(Electronic Systems and Communication)

By

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Rourkela, Odisha, 769008, India

May 2015

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Under the guidance of

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Dedicated to…

My Parents and my brothers

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA – 769008, ODISHA, INDIA

Certificate

This is to certify that the work done in thesis "**Adaptive MAC Protocol Design for Energy Efficient and Reliable WBAN link**" by **Bishnu Prasad Sahoo (213EE1294)** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Electrical Engineering during session 2013-2015 in the Department of Electrical Engineering, National Institute of Technology Rourkela is an authentic work carried out by her under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Place: NIT Rourkela

Date: 29th May2015

Prof. Susmita Das

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ROURKELA – 769008, ODISHA, INDIA

Declaration

I, Bishnu Prasad Sahoo, declare that this thesis titled, "**Adaptive MAC Protocol Design for Energy Efficient and Reliable WBAN link**" and the work presented in it are my own.

I confirm that:

- I certify that the work contained in this thesis is original and has been done by me under the guidance of my supervisor.
- The work has not been submitted to any other Institute for any degree or diploma.
- I have followed the guidelines provided by the Institute in preparing the thesis.
- I have confirmed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
- Whenever I have used materials (data, theoretical analysis, figures, and text) from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references.

BISHNU PRASAD SAHOO

29th May 2015

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ABSTRACT

The present need for a well-organised and continuous health care service at an affordable price gives rise to a wireless health monitoring technology.

Wireless body area network is an emerging field of a wireless sensor network that works in the vicinity of the human body. This technology has its most significant application in the modern healthcare system. This WBAN architecture is designed to get the health information and daily routine of human activity (both physical and psychological) through energy efficient and reliable radio transceivers connectivity These modern devices behave according to some predesigned rules called communication protocols. The MAC protocols are designed specially according to WBAN standards and requirements.

The physiological sensors installed in WBAN system consume a large amount of energy for communication that leads to frequent data interruption and also a change of implanted devices. As this is troublesome for both patient and server, protocols are continuously upgraded to make the communication highly energy efficient and reliable.

The prime aim of this work is to reduce the energy consumption and increase the lifespan of the network. This work proposes an energy harvesting adaptive MAC protocol applied for node connectivity and detailed simulation study carried out with the proposed protocol proves to be having minimum power consumption, increased network lifetime, and high throughput compared to the existing MAC protocols in WBAN framework. We have used Hybrid mesh topology where all nodes have both uplink and downlink. Here we are utilizing a GTS based multi-hop technique and adaptive wake-up mechanism for the sleep mode of the transceiver to minimize the wake-up periods.

TABLE OF CONTENT

NOMENCLATURE

E_c	:	Energy consumed per cycle
E_{ac}	:	Energy consumed during active state
E_{sl}	:	Energy consumed during sleep state
$(C.F)_i$	:	Cost function of node at i^{th} round
d_{jk}	:	Distance between j^{th} and k^{th} node
TS_n	:	n^{th} time slot allocated to node
T^{GB}	:	Guard period to avoid collision and clock drift
G	:	Guard factor
D	:	Acceptable delay
a_{if}, b_{if}	:	Factors to decide connectivity between nodes
d_{if}, d_{fs}	:	Distance between i^{th} node to relay node and distance between relay node to sink
T_{ac}, T_{sl}	:	Active and Sleep duration respectively
T_{fr}	:	Total frame duration
W	:	Channel link capacity
D_{pr}	:	Delay for proposed MAC protocol
P_{avg}	:	Average power consumption in proposed MAC protocol

ABBREVIATIONS

WBAN	:	Wireless Body Area Network
MS	:	Monitoring Station
MAC	:	Medium Access Control
TDMA	:	Time division multiple Access
CSMA/CA	:	Carrier sensing multiple Access/Collision Avoidance
LPL	:	Low Power Listening
QoS	:	Quality of Service
P2P	:	Peer To Peer
NID	:	Node identifier

HID	:	Hub identifier
MSDU	:	MAC service data unit
ACK	:	Acknowledgement
SYNCH	:	Synchronizations
CCA	:	Control Channel Access
CAP	:	Contention access period
CFP	:	Contention free period
TSR	:	Time slot request
SRR	:	Slot request reply
DR	:	Data request

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

Awareness of having a healthy life increases the popularity in daily chekup of physical activity and getting proffesional suggestion to avoid or to take precaution for any type of illness. This gives rise to new innovations for keeping an eye on human health activities through low power miniaturized sensors/gadgets also ascent to the advancement of gauges to give rules for the improvement of devices. Remote body system organizes additionally at times alluded to as body sensor system (BSN). IEEE formed a group to create norms for Wireless Body Area Networks (WBAN) according to practical scenario. This team has emerged as task group 6 (IEEE 802.15.6). Human tissue and organs can be damaged by high power transmission and also sesetive to frequncy of communication. So the gadgets must possess long and durable battery life and also required to transmit at low energy to upgrade their utilization inside or closeness to the surface of body so as to acquire an estimation or to apply the medicine. A consistent wellbeing checking of patients and infrequently utilization of pharmaceutical is the main intention of body area network. Despite the fact that BAN models are been designed for restorative objects, its handiness covers a scope of uses, like sports, entertainment, logistic and transportation, instruction and preparing, games and military.

The quick development and late mechanical advances in low-power incorporated circuits, remote communications, also, physiological detecting have prompted the improvement of little, lightweight, ultra-low power, smart wearable registering gadgets. These multi-practical versatile gadgets can together frame a wearable logging framework. A wearable logging framework can perform not just numerous of the same recording assignments as cell telephones and PCs be that as it may, additionally may incorporate sensors with biofeedback that empower the following of physiological capacities for individual wellbeing observing frameworks and recognizable proof frameworks .

Various these wearable processing gadgets can be incorporated into a remote body territory system (WBAN), which can encourage wellbeing checking and individual ID. Research into WBANs is testing yet is exceptionally important because of the large number of utilizations that WBANs have for social insurance and the checking of different human exercises. Research into low-control correspondence equipment and conventions can be connected to restorative finding or recovery, and customized frameworks. These application territories have profited from advances in physiological sensors, low-power incorporated circuits, and remote correspondence innovations.

A WBAN comprises of heterogeneous hubs with distinctive physiological sensors, for example, an electromyography (EMG), electrocardiography (ECG), human movement sensors, what's more, body temperature sensors. So as to keep up portability of the deliberate items for therapeutic or workout applications, WBAN requires every sensor hub without any wire associations. The individual sensor hubs will straightforwardly exchange the physiological information to an information accumulation unit. Figure 1 demonstrates the fundamental structural planning of a WBAN with different wearable sensor hubs for the reasonable medicinal application situation. These remote sensor hubs are conveyed inside or on an individual human body; the system can be depicted as a solitary jump system with a star topology [1]. The center point of the system is a sink hub and encompassing sensor hubs specifically send gathered data to this focal hub. In this paper, we propose the versatile transmission MAC convention concentrated on the single/multiple bounce remote connection with a hybrid peer to peer (or mesh) topology.

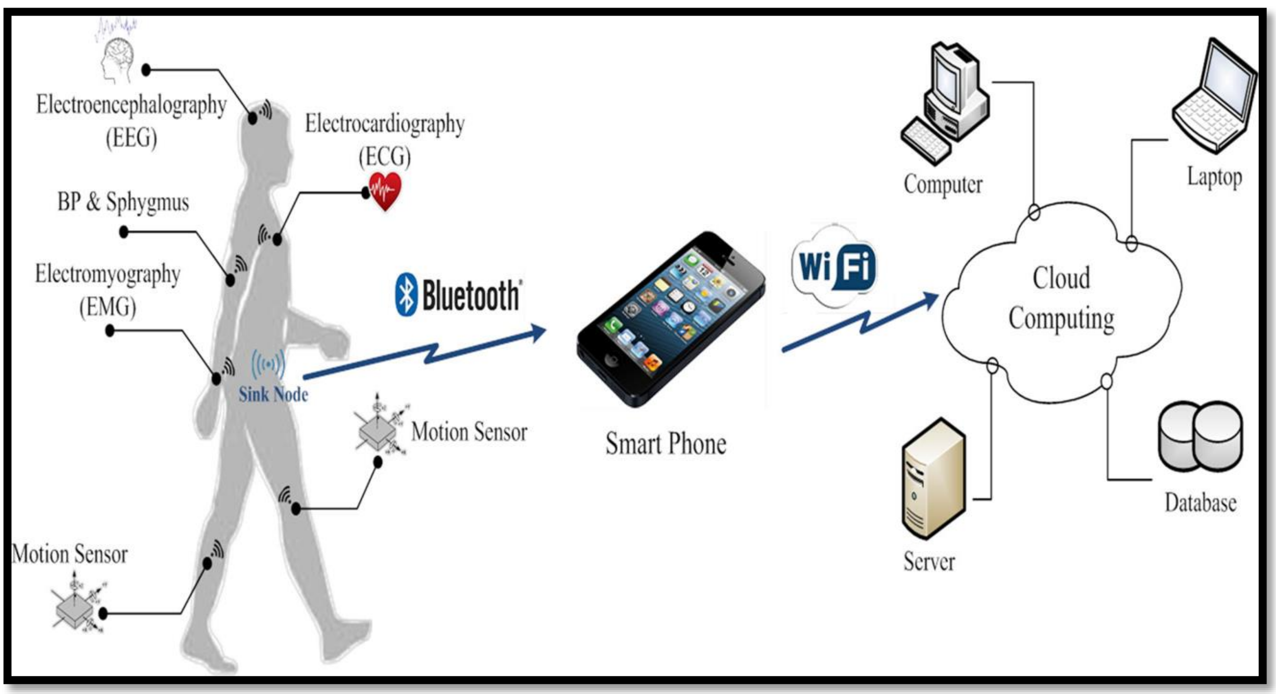


Fig.1-1[WBAN structural planning]

Given that the sensor hubs are normally battery-fueled, this minor battery typically places constraints on the sensor hub's lifetime [2]. In this manner, vitality effectiveness is imperative for these systems, particularly when planning a MAC convention. Energy effectiveness contemplations rule the configuration and advancement of all pragmatic MAC protocols. There are three primary methodologies for embracing energy sparing components in MAC protocols for WBANs: low power tuning in (LPL), planned controversy, and time division numerous entrance (TDMA) [3]. Out of these three methodologies, TDMA has the most minimal energy utilization on the grounds that it doesn't experience the ill effects of any conflict, unmoving tuning in, on the other hand catching issues, which are the primary variables of energy wastage.

Because of the wide mixed bag of sensor sorts in commonplace WBANs, information conveyance rates in these systems compass a wide range from low inspecting rates, In the event that sensor hubs with diverse testing rates are dealt with just as the execution of the system will be decreased by the lopsided movement load [4, 5]. In this way, a versatile information transmission instrument is essential to improve energy use in such a system. The transmissions of distinctive sensors are adaptively controlled by the MAC convention, as per every sensor hub's examining rate. High testing rate sensor hubs will have a bigger number of chances to convey information bundles than lower testing rate hubs. This ought to ensure that high testing rate sensor hubs have the capacity to transmit and convey the greater part of their gathered information. Moreover, lower testing rate sensor hubs can likewise go into longer rest modes to enhance energy efficiency.

1.1 Literature Survey

A single hop based MAC protocol is excogitated by Omeni et al. in [6] which uses fallback time for wakeup to avoid overhearing and collision due to continuous time slot. The synchronization is quite troublesome during busy traffic period as it is concentrating only on single node for hopping.

In [7] Timmons and Scanlon prepare MedMAC, which is based on TDMA approach. Involving Guard band between two adjacent slots helps to avoid overlapping.

S-MAC protocol in allocate duty cycles to each coordinator to minimize the idle listening. Here each node listens within the active timeslot and then goes to sleep when active period is over.

Trade-off between polling and contention with respect to the latency, energy consumption, and packet reception ratio is done by Boulis et al. [8]. However, the trade-off does not consider dynamic traffic variation.

Yselishchev et al. [9] try to reduce transmission loss through TDMA scheduling technique where node has better channel access probability within the time slot.

There are different Causes of energy wastage, some of them are- excessive collision, control packet overheads, ideal listening, overhearing. In [10] the authors proposed WBANMAC criteria such as energy efficiency in accordance with the support of simultaneous operations, and Quality of Service (QoS).

An opportunistic protocol is designed by author [11] which adopts to random node mobility at the cost of energy consumption and low throughput. As the sink is implanted on the wrist, the sensor nodes spend more energy to find the location of the sink. Sometimes if sink is not in the coverage area of the sensor, it fails to send data to sink node. As a result, of which it costs more energy and deteriorate the throughput.

1.2 Motivation

It is required to have primary data on patient's health behavior to fasten the medical health care system. This accumulation of primary data is done by implanted sensors around or inside the human body.

It is a challenging issue to monitor health ailments using wireless sensor network as monitoring patient requires high data reliability on different serious health problems. It also requires small implantable energy sophisticated sensor modes to keep a continuous monitoring health record. Some of these challenges are discussed in. To overcome the challenges faced by WSN new standards come forward which are include in wireless body area network (WBAN).

In 2007 IEEE, establish a group of committee member to standardize the WBAN scheme. These specifications [12,13] are being developed by IEEE task group 6 to be compatible to work with short range and low power human body implanted devices.

Unlike WSN, WBAN has its own distinguished features, which are the cause of technical challenges for the network. It has mainly two types of nodes; one is sensor or actuator, and other is relay or router. The data rate varies from application to application. But according to IEEE standards it is suitable within the ranges of 10m and for physiological inspection the data rate varies from 10Kbps to 10Mbps.

WBAN is a technology to get remote medical observations, where implanted sensor nodes scan the human body and sends health information to the destination node or hub stations. However, these embedded nodes consume power in the process of data sending and receiving. In this network, any physical change can actuate many sensor nodes at a single period that can cause unnecessary data transmission interference causing packet collision. As a result, of which there is again energy loss in the whole network.

Currently, researches are going on to lessen the energy consumption of nodes so that system can work efficiently. As MAC layer controls, the radio activities hence many MAC protocols are coming up to make the node communication less energy consuming so that network life period can be enhanced. Recently researchers are motivated towards diminishing the challenges faced in WBAN field. So different innovative MAC protocols are coming forward.

1.3 Objective

The main objective of the research is to design an adaptive protocol for WBAN system so as to make the communication more energy efficient which eventually results in higher network life and improved throughput. The designed protocol is meant to adapt different traffic behavior of the channel and respond accordingly. The realization of the objective is done through following investigations and analysis:

- ❖ The mac layer frame structure has been designed using IEEE 802.15 WPAN and WBAN standard for short range communication purpose.

- ❖ Study of different MAC protocol like SMAC, BMAC, WiseMAC, XMAC and then comparison of the protocols with each other for analyzing the behavior.

- ❖ Implementation of adaptive protocol under hybrid topology based scenario and comparison with IEEE 802.15.4 and IEEE 802.15.6 network to analyze the performance of protocol.

1.4 Thesis Contribution

Current research area in WBAN is mostly concentrating on energy minimization techniques inside MAC layer to enhance the WBAN network lifespan. An energy efficient adaptive MAC protocol has been designed to make a WBAN connectivity link more reliable. Contribution of the thesis is discussed below.

- An energy effective cost function based multi-hop technique has been proposed to reduce transmission energy loss and an adaptive synchronization mechanism has been proposed for TDMA based MAC frame to lessen the effect of clock drift.
- The proposed MAC protocol has been compared against some existing protocols like WiseMAC, BMAC, SMAC and Zig-Bee protocols.
- Detail mathematical analysis has been carried out to compare and validate the performance of the proposed protocol for a whole WBAN network.

1.5 Thesis Organization

The thesis has been organized in to six chapters. The ongoing chapter gives the brief introduction to the spectrum shortage, fixed spectrum allocation strategy, cognitive radio, and spectrum sensing. The motivation and objective of the thesis have been addressed in the following subsections, although the uttermost subsection explains the entire thesis organization and literature survey.

Chapter 2: The second chapter discusses the detailed description of wireless body area network including its architecture, applications, design requirements and also the causes of energy wastage

Chapter 3: This chapter introduces the design architecture and functionality of medium access control layer. A brief overview of MAC layer architecture based on IEEE 802.15.6 standards has been given here.

Chapter 4: This chapter gives light on, the energy efficient techniques that are being used to design MAC protocols. This chapter also gives brief description and comparison about existing MAC protocols.

Chapter 5: Design of the proposed energy efficient and reliable adaptive MAC protocol is discussed in this chapter. This chapter includes the comparison of proposed MAC protocol with the existing MAC protocols, and simulation analysis of the whole WBAN system using proposed MAC protocol has also been presented here

Chapter 6: This chapter assembles and concludes the entire research work carried out and tells about the future scope to the research that has been confabbed in the thesis.

Chapter 2

Wireless Body Area Networks

BAN consists of short-range devices with low level energy. It has various application which in the vicinity of human society. The applications aim medical services (mostly), it also includes entertainment and gaming. In other words BANs is a unique Wireless Sensor Networks that has small number of nodes and has high reliability with much signifanct QoS as compared to the traditional WSN.

2.1 Introduction

WBAN is an assemblage of tiny, flexible behavioral, and low energy based wireless sensors to supervise any physiological changes around the human. In WBAN human wears some sensors which helps in monitoring the different parameters related to human health and then sends the accumulated information to a coordinator node or hub. This Coordinator node can either be a normal hub, or be a forwarder node that forwards data. Coordinator node further transmits monitored data to a main base station for processing through a wireless access point (AP). This AP can be a smart phone or can be a coordinator node itself as per the applications.

Sometimes sensor nodes have actuator to convert an electrical signal into physical signal like motion for pumping. A sensor in WBAN has a primary job to sense any change in physical, chemical or biological entities inside human or arround its vicinity. Then they send the data for further treatment like filtering, amplifying or digitizing the signal for extracting the features. Then the processed signal is stored and further ready to be sent to the gateway through a wireless radio channel. This gateway or hub is a high power device used to gather and process the data ttransmitted by the sensor nodes. Hence the gateway should be capable of doing accurate computations. The sink either provides direct feedbacks visually or vocally to user or forwards data through a wireless network, which may be a WLAN, GPRS, UMTS, or (Wi-MAX), etc. [14], to a distant server for real-time inspection or post-analysis.

2.2 Architecture of WBAN

Body area network is based on different attributes. Such as:

- Hardware platform
- Topology of network
- BAN Communication Technology
- Operating Software for base station
- Deployment of sensors
- Physical environment
- Energy source

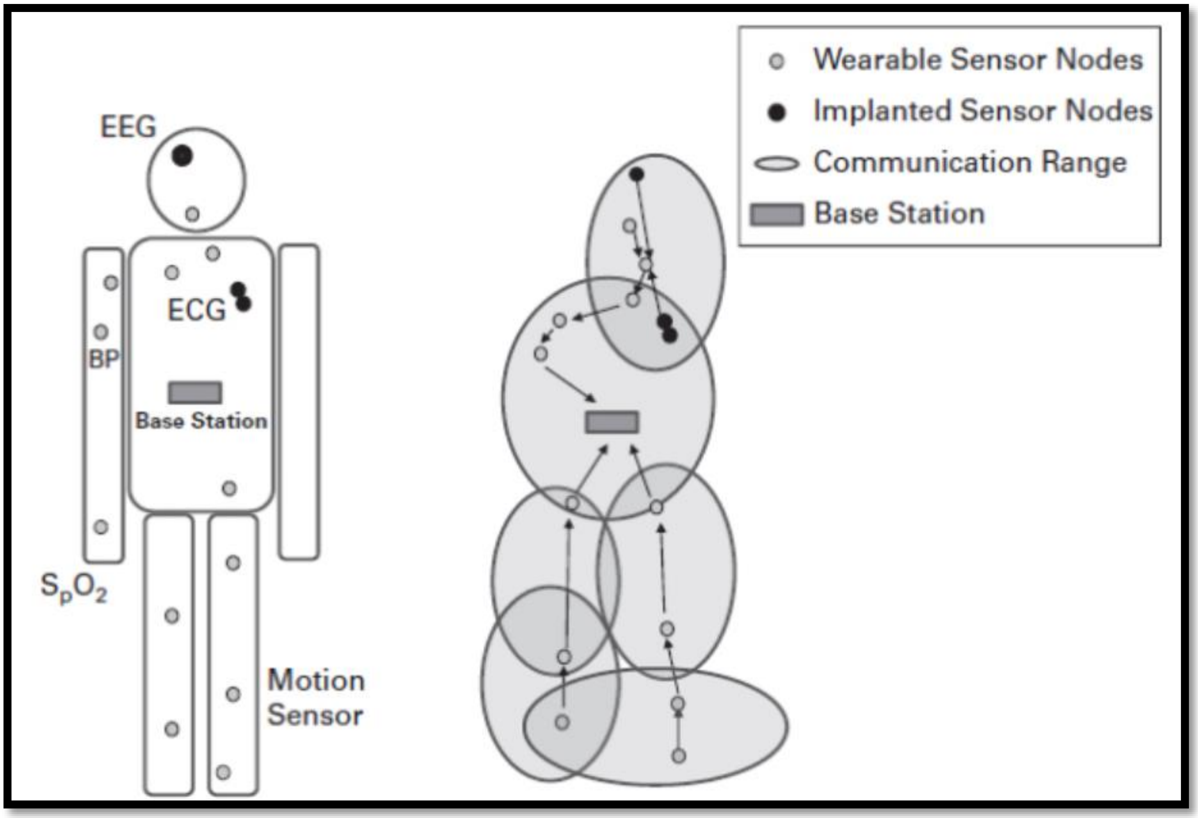


Fig. 2-1[BAN architecture]

2.2.1 Hardware platform

BAN contains several hardware components to fulfill variety of jobs. These hardware are according to their primary function and are as follows:

- It needs some general purpose sensor to measure and compare different human surrounding conditions.
- Then some medical equipments are employed to get information on health.
- To accumulate the information some data aggregator (image collector) are installed inside whole network
- Finally an access point or gateway (smartphone) is required to store or communicate data.

2.2.2 Topology of Network

The BAN committee has recommended some network topology having a single hub and number of nodes.

A simple single-hub network topology is shown in figure 2-2 [15]

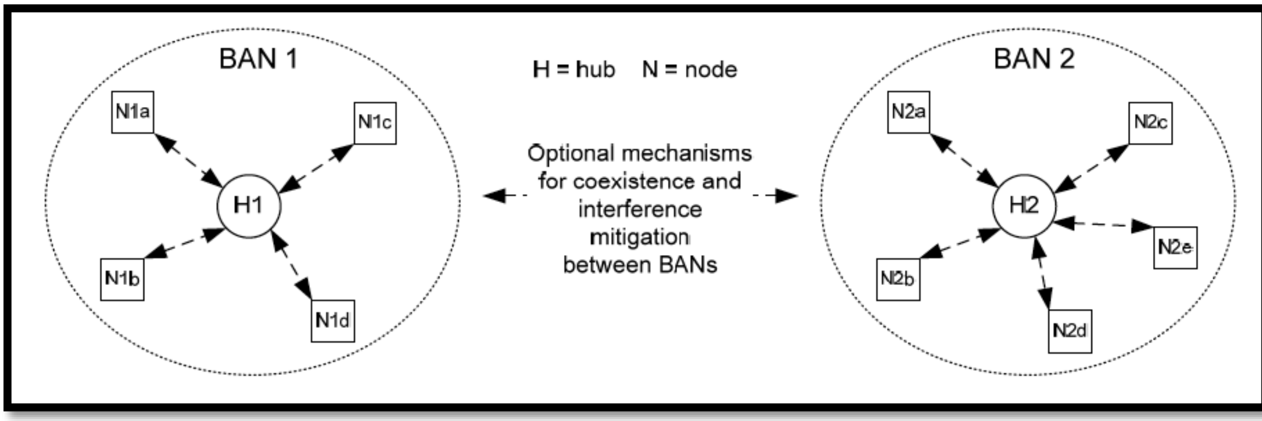


Fig. 2-2[single hub network topology]

As WBAN is a subfield under short range communication group of WPAN (802.15.4), Concerning networking capability, two topologies have been decided for 802.15.4. One of them is a fundamental star (Fig. 2-3a). All interchanges between hubs must go through the center coordinator node. A common peer to peer (P2P) topology can be defined (Fig. 2-3b). Any device may just then speak to some other gadget. This general topology may be increased into other topologies in the upper community layers, such as the preferred mesh topology.

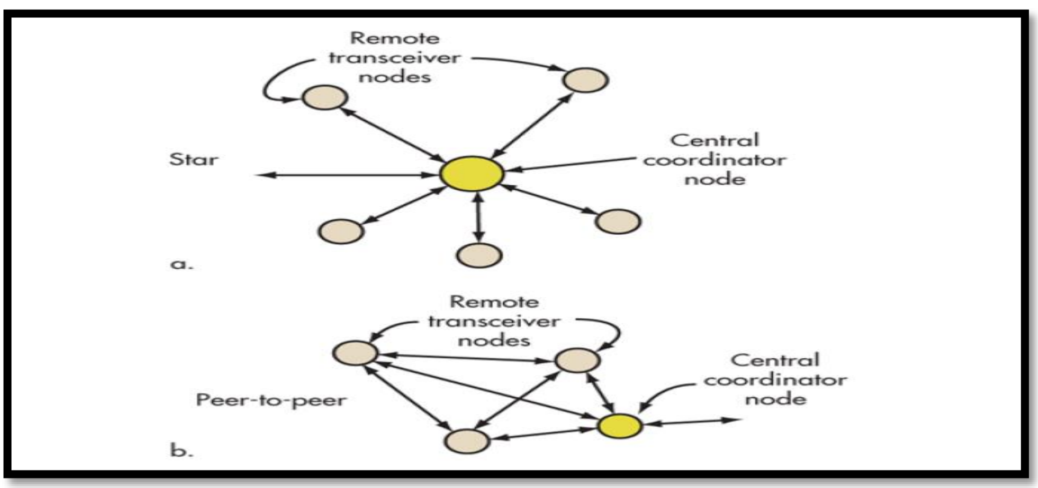


Fig. 2-3[hybrid topology]

A mesh network is a type of hybrid topology under P2P architecture. It has got certain benefits such as:

- Any node can be in contact with another node, if not straight if within range then through other relaying nodes
- The whole network then can disperse over a larger area.
- There are alternate paths through which the system sustain a connection if any node dies out. Hence, it increases reliability.
- Mesh networks are self-configuring and self-healing.

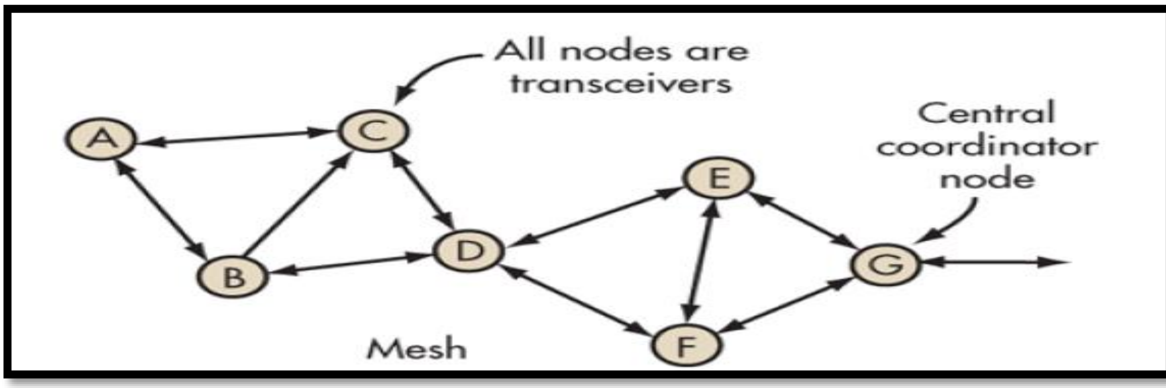


Fig. 2-4[mesh topology]

2.2.3 BAN Communication Technology

Based on frequency of transmission, range and power consumption different types of communication technologies are coming forward. BAN has five layers in its protocol stack, but it has heavy application based on physical layer and medium access control layer. These layers do particular tasks to assure continuous communication within nodes and node to hub. [16]

- The PHY layer acts according to radio frequency band and antenna specifications.
- MAC layer deals with communication stratergies between lower PHY layers to upper layers.
- Network layer suggests reliable data exchange and control procedures.

2.2.4 Sensors Distribution

In BAN sensor distribution and installation is application basis and the purpose of node for the application. Sensors can be installed on or within the human body as per the application requirements. For example, sensors are deployed to monitor or deliver medications to patients in health monitoring system. The figure below gives an idea of sensor deployment.

2.2.5 Physical Environment

Though BAN has various applications, it is mainly focused on medical care system. Hence human body is mostly used physical environment. For sensor nodes environmental influence is a crucial part which depends on type of deployment also.

2.2.6 Energy Source

BAN devices have to be connected wirelessly to ensure mobility with no obstruction of movement, Thus, there should have wireless access between sensing nodes and hubs. To achieve smooth wireless communication nodes and hubs should have independent energy sources. The basic energy source in BAN system are Batteries. The batteries can be rechargeable or non-rechargeable based on the BAN application.

2.3 Application of BAN

The design of Body area networks (BANs) confines within the coverage region to the human body. The WBAN is an essential technology to realize convenient steady monitoring with the aid of disposing of physical wires. To maintain a good body alignment and BAN is applied in four primary ways. BAN is designed for both medical and non-medical application.

2.3.1 Medical

In late, the level of data gave and vitality assets fit for driving the sensors are progressing. Innovation has helped to evolve BAN technology in the advancement of medical field and give birth to telemedicine and mHealth care systems. Essentially uses of BANs are relied upon to show up mostly in the social insurance area, particularly for ceaseless checking and several basic parameters of patients experiencing acute illnesses, Normally a BAN system is put on a patient to alarm the healing facility, even before they show at least a bit of kindness assault, through measuring changes in their basic signs.Figure 2-5 below shows the BAN medical scenario.

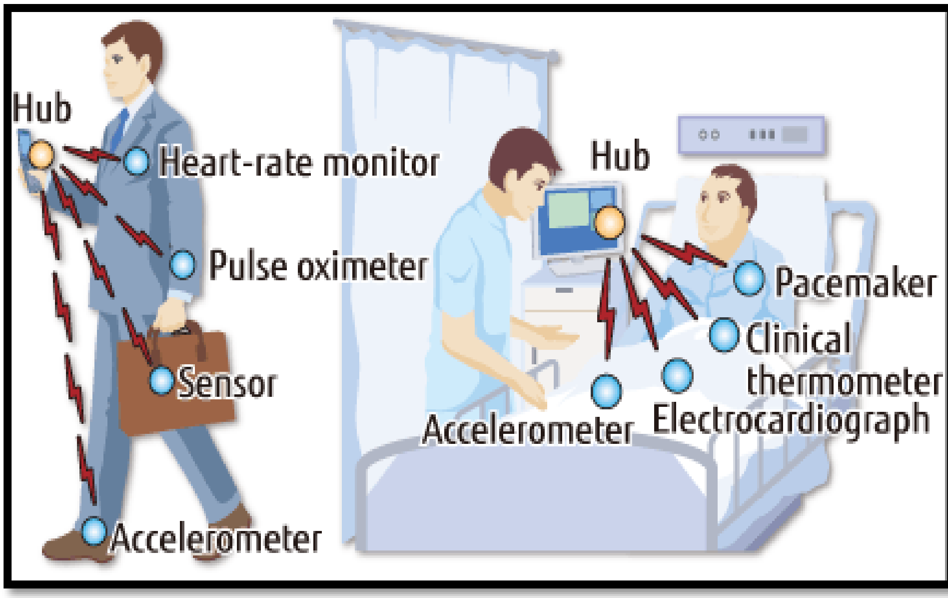


Fig. 2-5[BAN for medical application]

2.3.2 Sports

BAN has expanded its application area beyond medical field. It is now a days used in sports field to scrutinize the athletics' health for their better performance in maintaining physical activities. Recently wearable sensors are being used in games, which examines the limit of the muscles. In sports BANs an arrangement of remote sensors are used to take certain readings of competitors and also ordinary individuals. These sensors accumulate as well as compare the health statistics to give show the condition of athletics as well as normal people.

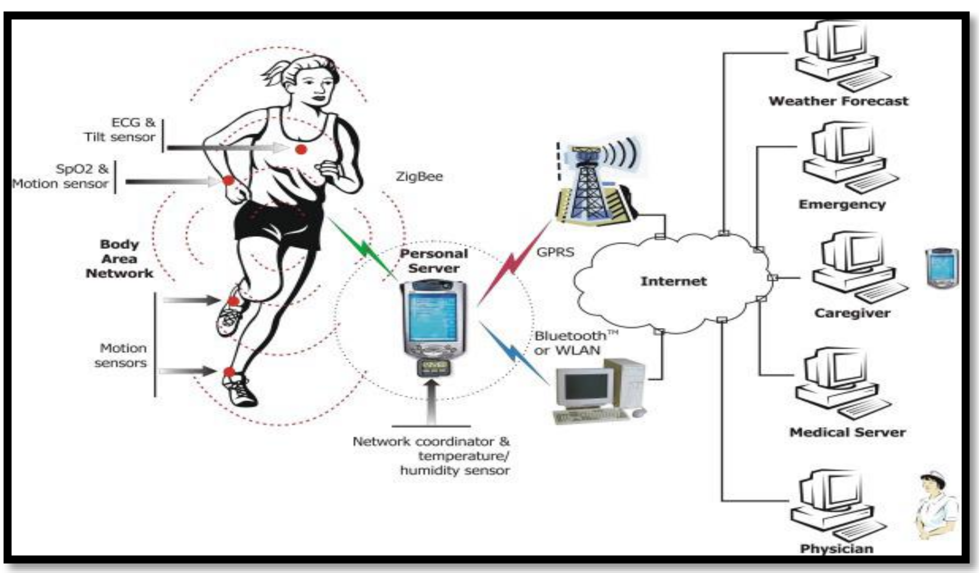


Fig. 2-6 [Schematic diagram of the proposed sports BAN]

2.4 Design Requirements

In WBANs, sensors collect various information from the patient body and communicate with the coordinator. For active patient health monitoring systems, Latency and transmission reliability are some of the crucial requirements. Similarly, WBANs requires high energy efficiency and scalability for long term monitoring.

2.4.1 Data rate

As body area network is an application based system, the data needed also varies for different applications. Hence data rate also varies from few Kbps to several Mbps according to the necessity level of applications. That means the emergency data packets to attain a serious condition have to have high data transmission rate with low latency.

Application	Target Data rate	Latency	BER
Drug delivery	< 16 Kbps	< 250 ms	$< 10^{-10}$
Deep brain stimulation	<320 Kbps	< 250 ms	$< 10^{-10}$
Capsule endoscope	> 1 Mbps		$< 10^{-10}$
ECG	192 Kbps	< 250 ms	$< 10^{-10}$
EEG	86.4 Kbps	< 250 ms	$< 10^{-10}$
EMG	1536 Mbps	< 250 ms	$< 10^{-10}$
Glucose level monitor	1 Kbps	< 250 ms	$< 10^{-10}$
Audio	1 Mbps	< 20 ms	$< 10^{-5}$
Video/Medical imaging	< 20 Mbps	< 100 ms	$< 10^{-3}$
Voice	50-100 Kbps per flow	< 10 ms	$< 10^{-3}$

Table. 2-1 [WBAN application datarate]

2.4.2 Energy Effective

Power effectivity is the first intention to acquire in WBANs as sensor nodes are fueled by small power batteries. So it is a dire requirement to minimize the power consumption for long term monitoring of health . Different dynamic energy management schemes can be implemented to increase the longivity of sensors.

2.4.3 Reliability

Reliability is the successful transmission of information through any channel. BAN mostly contains information regarding health issues which are necessary parameter for judging and medicating any disease. Hence BAN should have a greater reliabilty to be in the good book of everyone. This reliability depends on parameters like packets transmission delay and packet loss probability. Guessing of correct channel, packet dimension, and scheduling schemes at MAC layer can fortify reliability of BAN system.

2.4.4 Scalability

For BANs scalability is one of the common requirements. The hub quantity, to gather crucial and non-crucial life jeopardising data, changes as indicated by patient checking necessities. Effortlessly setup of WBANs by including or evacuating sensor hubs is obliged to bolster adaptability. Mac layer can accomplish this flexibility.

2.4.5 Quality of Service (QoS)

BAN should be versatile enough to confirm various QoS levels to guarantee sucessful reception of information. QoS in BAN is a challenging issue to handle but this can be solved by coordinating network layers through different protocols. QoS entities vary from application to application according to importance level. Packets must be communicated in a reliable manner to get good QoS.and life endangering situations must be given high priority.

2.5 Cause Of Energy Wastage

Senors used in BAN system have very small amount of battery power as it is mostly used around human. Hence replacement of batteries or recharging of batteries is quite impossible.As a result of restrained source, there ought to be strict management system to keep this energy wastage within limits. Therefore, it is a big issue for BAN sensor to minimize energy consumption.

A. Collisions of packets: The transmission time and energy get wasted if nodes transmit data packets simultaneously at concurrent periods. This results due to heavy collison and interference between concurrent data packets arrived in same channel. At the receiver end, Collision of Packets happens due to which there is packet loss and sender tries to resend the dropped or lost packets. This Retransmission of lost packets causes extra energy dissipation.

B. Overhear of nodes: To avoid packet or data loss nodes try to overhear neighbour packets to resend on behalf of the sender. Acquiring and transmitting these extra packets cause extra energy consumption of nodes.

C. Idle listening: In idle listening, sensors expect to listen other idle channels also which requires extra energy.

D. Protocol overhead: If size of ovrehead increases it needs more energy to transmit large overheadpacket

State switching also causes additional energy consumption, which happens when a sensor node swaps its transceiver from sleep to active mode of transmitting information and then again to returns to sleep mode for preventing idle listen and overhear issues of system. In the subsequent chapters, different kind MAC protocols are discussed to make the procedure energy efficient.

Chapter 3

Medium Access Control layer design and architecture

The second lower layer above physical layer is medium access control (MAC) layer. This MAC layer is responsible for sharing of data and communication to the upper layer. The efficiency of sensitive wireless communication depends, on the extent, of the effectiveness of this l Medium access control (MAC) layer. Access the medium by the nodes is determined by a MAC protocol which controls the MAC layer operation.

3.1 Overview of IEEE 802.15.6 MAC Layer

This part talk about in regards to the WBAN MAC layer basics. It covers MAC layer frames as per exclusive WBAN physical layers.

The nodes coordinate into single or multiple hops according to IEEE 802.15.6 standard, WBANs. A single coordinator or hub handles the overall operation of each WBAN network. The direct frame exchange between nodes and hub occurs in single-hopped star WBAN whereas relay nodes come to picture for star network.

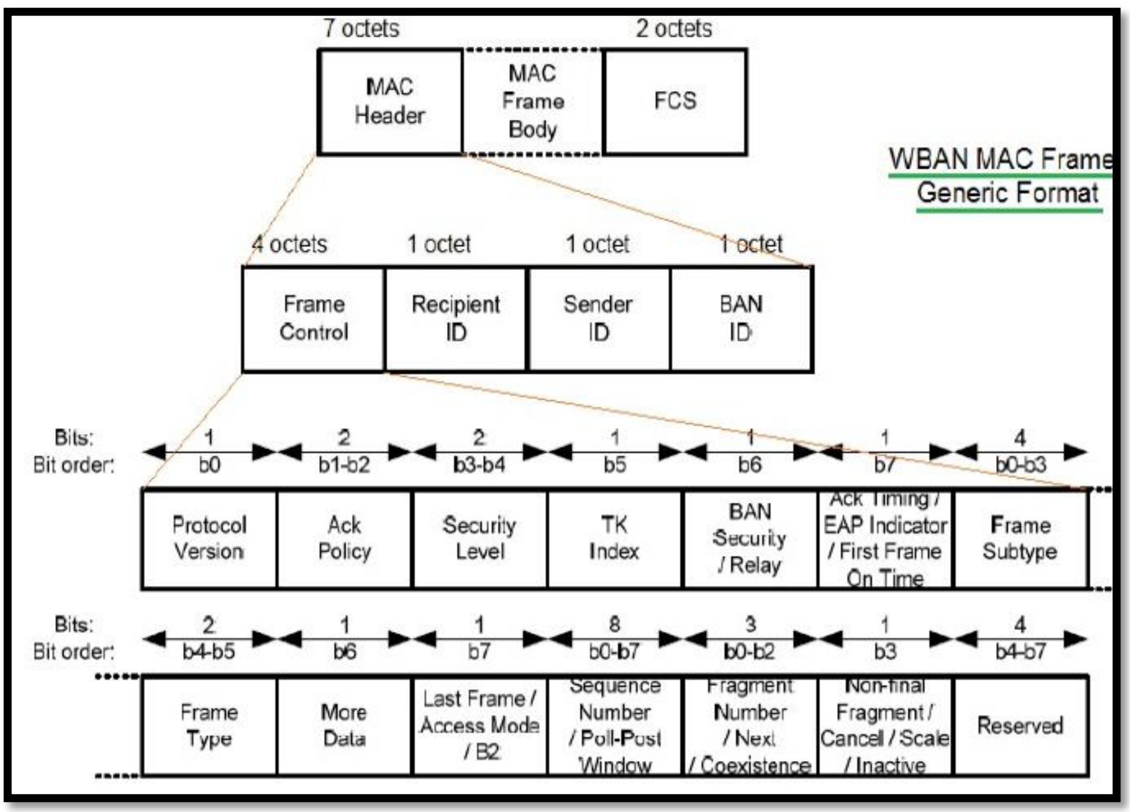


Fig. 3-1[WBAN MAC frame structure]

3.2 Functions of The Media Access Control (MAC)

The MAC performs a couple of procedures to make sure that destined node got the frames sucessfully and correctly. [16] They are as such:

First of all processing of frames is done, then the frame is classified an devided into several type like normal or emergency frame. Then BAN is created depending on access type like random acccess or scheduled/unscheduled acess. Time synchronization and guard period is provided to avoid coexistence and to mitigate interference as well as energy.

3.2.1Frame Processing

Frame processing is done through addressing the nodes and hubs. Different addressing methods are discussed below.

A. Truncated Addressing

In this type of addressing method network identifiers are used for providing comunication location. Each hub selects an identifier (ID) for communicating purpose. The header of MAC frame contains this BAN identifier which is a single octet value ranging 0X00 to 0XFF. The MAC header also has two different BAN identifier one is a HID and other is a NID. The HID provides the ID of such a hub which is not used by other neighbouring hubs and is selected from a subset of node identifier while the Node ID is selected from group of nodes and used for abbreviated addressing of nodes.

B. Full Addressing

Extended unique identifier-48 (EUI-48) is used to address a hub. The exact value of EUI is incorporated within the payload to specify the management frame characteristic. The received address of management frame is checked to ensure the frame are sent by expected senders.

C. Priority Mapping

BANs is primarilly designed for health care application, and this application may contain some critical information. Hence Prioritization is one of the necessity to distinguish these health care application form other BAN application. The frame payloads denomination confirms type of user priority (UP).

Priority	User priority	Traffic destination	Frame type
Lowest	0	Background (BK)	Data
	1	Best effort (BE)	Data
	2	Excellent effort (EE)	Data
	3	Video (VI)	Data
	4	Voice (VO)	Data
	5	Medical data or network control	Data or management
	6	High-priority Medical data or network control	Data or management
Highest	7	Emergency or medical implant event report	Data

Table. 3-1[Pay load with user priority]

Table 3-1 illustrates the payload type and user priority [17]

3.3 Frame Incursion

Modes of process received frame (by IEEE 802.15.6)

The node ID (NID) and the hub ID (HID) in the MAC frame of a receipint is determined respectively.

The sender ID becomes NID for the hubs whereas the same ID acts as HID for other nodes.

Then the probable value is determined for body area network identifier.

Parties involved in frame exchange buiseness abide by the protocols.

3.4 Frame order

IEEE 802.15.6 has specified two frame types, one is management frame and other is data frame for this reason, specifications are povided for sequencing of frames. Sender node receives management type frame when node gets any immediate acknowledgement from the receipient. However the data type frames (MSDU) are transmitted as per the arrival of data at MSC . The transmitted MSDUs are extracted and transmitted to MSC client. [16]

3.5 Frame retransmission and frame timeout

Frame retransmission takes place if the the receiving node failed to get the frame which is sent to it. The frame the hub or node takes reliability, delay requirement, and channel condition into account before retransmitting the frame. However if the frame fails to arrive the destination within the assigned timeslot or after the end of physical preamble frame, then frame timeout situation comes to picture. [16]

3.6 Frame classification

Frame classification has been distinguished into two catagories as per the IEEE 802.15.6 and are based on sender and receiver role. A hub or node separates the frame and then despatches to receiving node and in return receiving node does the same according to the requect of the sender. The recevier node should continue receiving untill the timeout, indicating the termination of the preamblle of expected frame.

3.7 Frame Acknowledgement

The plan of acknowledging a frame is decided by the frame header of MAC frame sent from sender node. However the receiver node must obey the acknowledgement policy of sender node so that fluent frame exchange buisness can take place. IEEE 802.15.6 has specified some acknoeledgement policies which described below.

Frame type name	Frame subtype name	Ack Policy field
Management	Beacon	N-Ack
	Security association	I-Ack
	Security disassociation	I-Ack
	PTK	I-Ack
	GTK	I-Ack
	Connection request	I-Ack
	Connection assignment	I-Ack
	Disconnection	I-Ack
	Command	I-Ack
Control	I-Ack	N-Ack
	B-Ack	N-Ack
	I-Ack + Poll	N-Ack
	B-Ack + Poll	N-Ack
	Poll	N-Ack
	T-Poll	N-Ack
	Wakeup	N-Ack
	B2	N-Ack
Data	Data subtype set to mG-AckDataSubtype	G-Ack
Data	User-defined data subtype other than mG-AckDataSubtype	N-Ack, I-Ack, B-Ack or L-Ack

Table. 3-2[frame acknowledgement policy]

Chapter 4

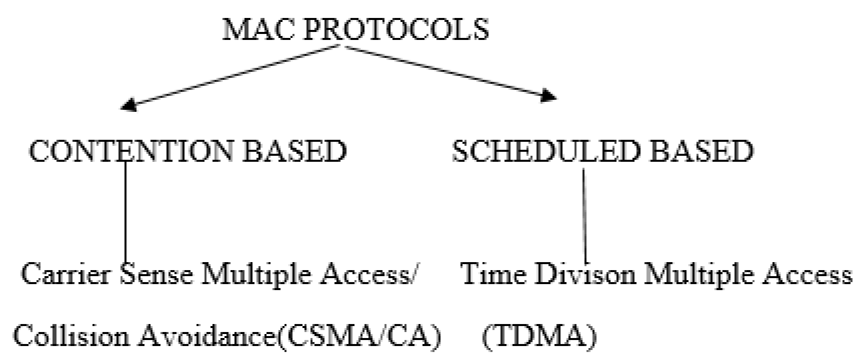
Medium Access Control protocols

Our objectives in WBAN are as follows:

- Maximize throughput,
- Minimize the delay, and
- Maximize the network lifetime

These objectives above are achieved by commanding the sources of energy wastage that are discussed in the previous chapter.

To avoid the causes of energy degradation, the data transmission, and nodal behavior should be efficient which are handled by Medium Access Control (MAC) protocols.
Protocols are sorted on the basis of contention and scheduling.



CSMA/CA

- Nodes compete for transmitting data.
- If the channel is busy, the node defers its transmission unless it turns into idle.
- Scalable without any time synchronization constraint.
- Uses significant protocol overhead.

TDMA

- Channel is slotted according to time which are assigned to nodes
- Protocols are energy conserving.
- duty cycle of radio is reduced.
- Hence, no contention, idle listening,overhearing problems. But these protocols require frequent synchronization.

Comparison between CSMA/CA access and TDMA access techniques are described in the table below.

Performance Metric	CSMA/CA	TDMA
Power consumption	High	Low
Traffic level	Low	High
Bandwidth utilization	Low	Maximum
Scalability	Good	Poor
Synchronization	N/A	Required

Table. 4-1[CSMA/CA vs TDMA access protocol]

4.1 Requirements of WBAN MAC

An essential quality of a decent MAC convention in WBAN network is the effectiveness in energy consumption. For some applications, where gadget ought to bolster a life of battery for several months to years without any dispute, while some may oblige a battery durability of just several hours because of the application types. Power-effective and adaptable obligation cycling methods are obliged to minimize the idle tuning in, overhearing, collision of packets and packet overhead issues. Besides, low duty cycle hubs ought not get continuous synchronization and beacons if they got no information to communicate.

In WBAN the medium access control ought to backing synchronous operation of in-body as well as on-body frequncies [(ISM) or (UWB)] in meantime. As such, it ought to bolster Multiple Physical layers (Multi-PHYs) correspondence. Other essential elements are versatility also, flexible enough to adapt to any modifications of the system, delay, data transfer bandwidth usage and throughput. MAC should be able to handle the system topology change, the movement of nodes, and the node density quickly and effectively. The SAR properties of human tissue and the traffic variation due to movement nature of bodily nodes has to be considered by MAC convention in WBAN.

In a WBAN, traffic is mostly interdependent, i.e., a patient experiencing any illness may actuate the temperature sensor, blood pressure sensor and related sensors simultaneously [18]. These progressions might likewise influence the level of oxygen contain in the blood. These sorts of medical entity affects the nature of the traffic. A CSMA/CA convention experiences overwhelming collisions and additional power utilization in handling the situation. Additionally, for CSMA/CA convention, Clear Channel Assessment (CCA) is done by nodes before packet transmission. Bin et al. examined the CCA reliability for WBAN and concluded that it is unreliable at -85 dBm[19]. Ullha et al. have investigated Carrier Sensing Multiple Access protocol under high traffic scenario and finally resulted that heavy traffic load affects the protocol adversely .

TDMA-based conventions give great answers for the traffic demand, dense collision, and CCA issues. These conventions are of energy saving nature on the grounds that the duty cycle is lessened, and also there are no conflict, idle listening, and overhearing issues. Then again, normal TDMA needs additional power for occasional time synchronization. The synchronization is done through periodic packet reception. Therefore new TDMA MAC protocols are required to be designed and implemented so as to tackle the diversified WBAN traffic problem in an power efficient way

4.2 Techniques for energy-efficient MAC protocol

Energy efficienct methods play vital role in the execution of a decent MAC convention. These methods are classified as per the listening power, contention, and time slot allocation. There is a brief description of methods below.

4.2.1 Low-powered Listening (LPL) Method

In LPL technique hub goes to sleep mode if it has no data to transmit. The LPL is performed on customary premise paying little attention to hub synchronization. A long preface is sent by sender before every message with a specific end goal to identify the surveying at the less than desirable end. The WiseMAC [20] convention is taking into account the LPL technique. In this convention, a unsteady Carrier Sensing Multiple Access and a preface inspecting procedure is utilized for improving the idle listening issue.

In a WBAN, the LPL component has a few favorable circumstances and detriments. The occasional testing is effective for high-activity hubs and performs well under variable movement conditions. Nonetheless, it is ineffectual for low-movement hubs, particularly in-body hubs, where occasional examining is not favored because of strict force limitations. Since the WBAN topology is a star topology and a large portion of the movement is uplink, utilizing LPL component is not an ideal answer for backing both in-body and on-body correspondence all the while.

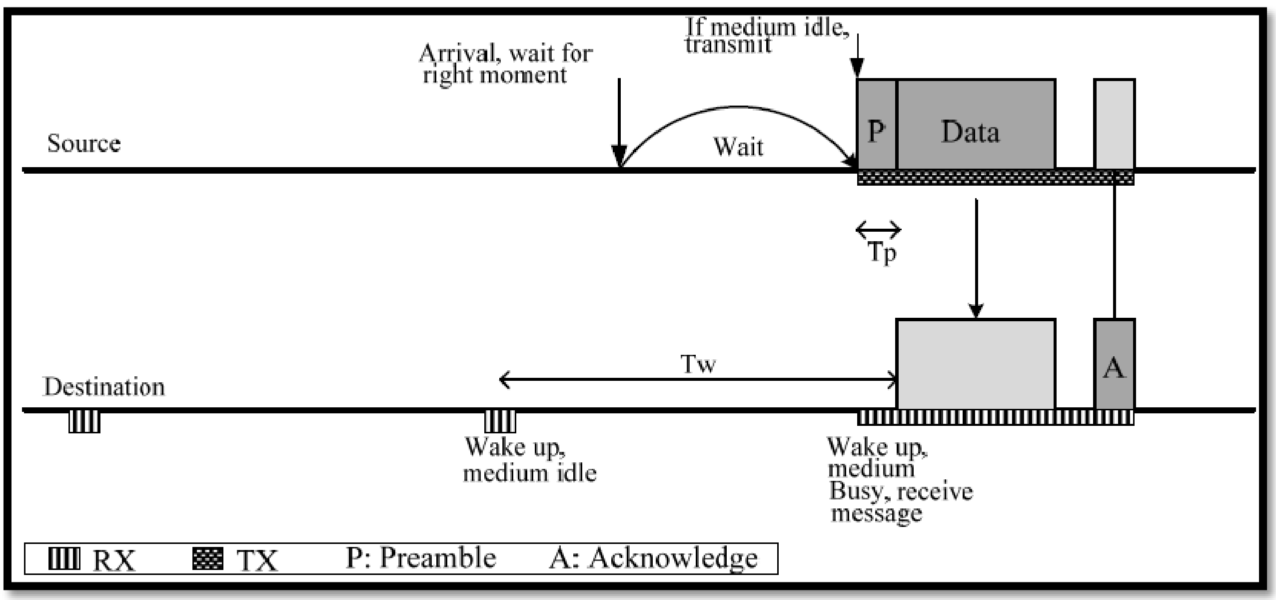


Fig. 4-1[LPL scheme communication]

4.2.2 Scheduled-Contention Mechanism

It is a combination of both scheduled based method and contention based method for achieving scalability as well as to dodge the collision. In this technique, the sensors share a common data communication timetable. During a synchronization interval, periodic schedule exchange takes place. For nodes belonging to different clusters have to keep schedules of each other with their own cluster schedule that causes for excessive energy requirement. In [21] authors proposed S-MAC protocol as an efficient model for scheduled-conntention mechanism. This is a protocol for multi-hop wireless sensor network based on contention and power efficiency. Use of schedules for sleeping helps in reducing idle-listening and shows good performance for multi-hop WSNs. Moreover this mechanism performs well for on-body communication but it is not suitable for irregular emergency and on-demand situations which needs frequent update of coordinator within short time slot.

4.2.3TDMA Mechanism

In a TDMA technique, the channel is allocated with time slot by coordinator node or base station. The time allocation is based on the traffic requirement. That means a node acquires a time slot only if it has data to transmit or receive. Though it proves to be the best in power efficiency it requires extra energy for frequent synchronization. The PB-TDMA is a TDMA based protocol designed for collision-less communication. Figure below shows a frame structure containing preamble and slots for transmitting data. Node responds to channel during preamble and transmits its' data within transmission slots.

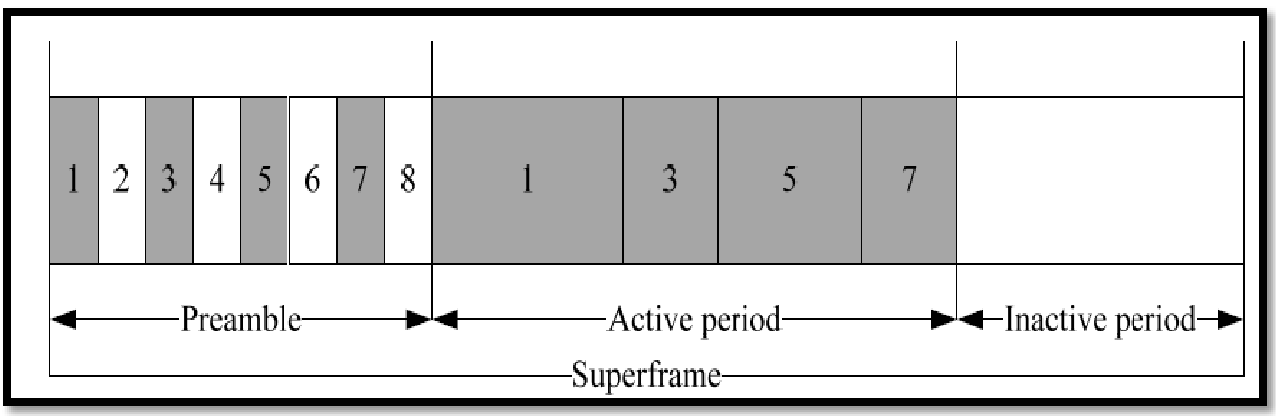


Fig. 4-2[superframe structure for TDMA scheme]

4.3 Existing MAC Protocols for WBANs

4.3.1 S-MAC

This convention presents the idea of synchronized sleeping among neighboring nodes. The node becomes active during data transmission otherwise it is totally turned off. The causes of energy consumption are diminished by this concept. The nodes trade control data with the beginning of frame wake-up period. A sleep duration follows every wake-up duration. In the event that a hub has information to send within in the sleep period, it must concede its transmission until the following wake-up duration.

Hubs keep up synchronization by sending SYNCH packets. this packet is of small size and contains information regarding the following sleep duration. The hub listening period is separated into two sections when both synchronization packets and information packets reached simultaneously. Figure 4-3 shows the timing relationship in the middle of get and distinctive senders. First Sender sends a Synchronization packets only. Then second Sender sends a unicast Information packets only. And third sender tries to sends both a Synchronization and an Information packet.

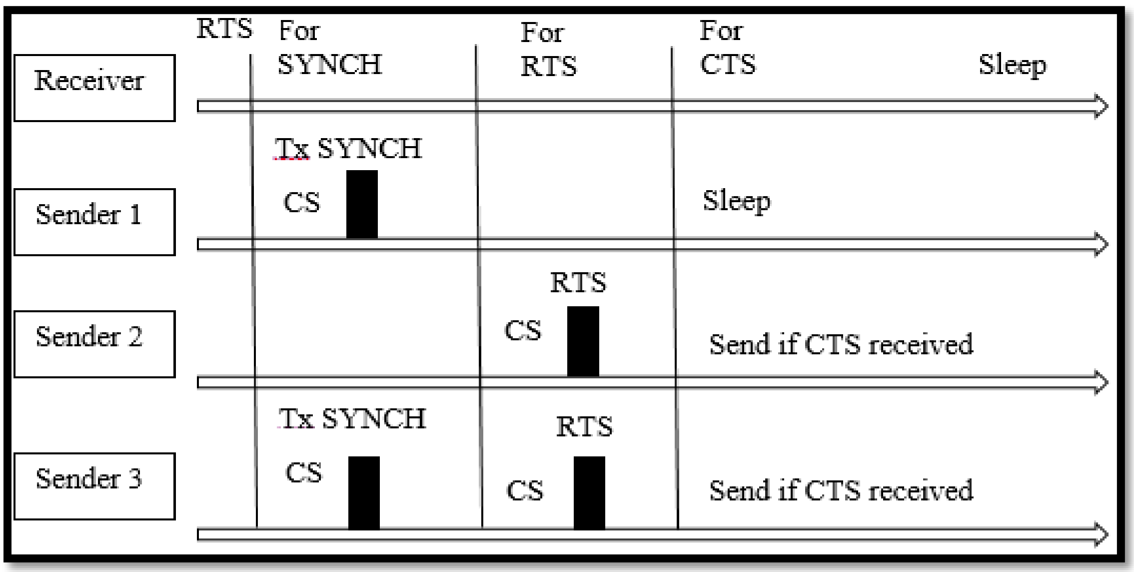


Fig. 4-3[S-MAC scheme]

4.3.2 B-MAC

- This protocol uses duty cycle which are asynchronous in nature.
- for complete communication protocol needs to send long preamble frames.
- It has to check for channel clearance frequently as duty cycles are asynchronous in nature.
- The coordinator node sends consecutive preamble and awaits for acknowledgement packet (ACK) from receiver side to complete the communication successfully.

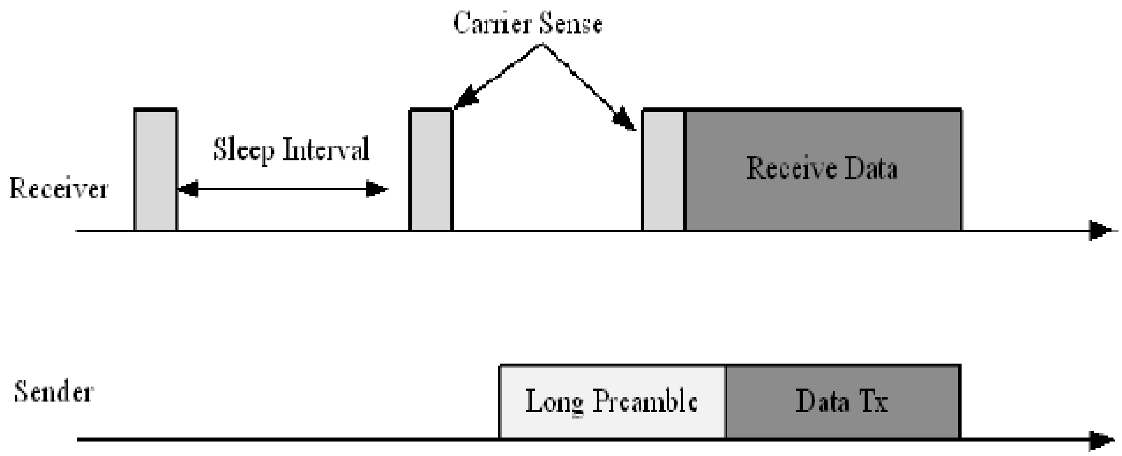


Fig.4-4[B MAC scheme]

4.3.3 WiseMAC

- This protocol makes the access point to learn about the schedules for sampling of other nodes.
- This helps the AP to decide the correct starting time for transmission.
- This learning also helps to minimize wakeup period used for preamble transmission.
- By learning the schedules of neighbor nodes, it decides length of the preamble.

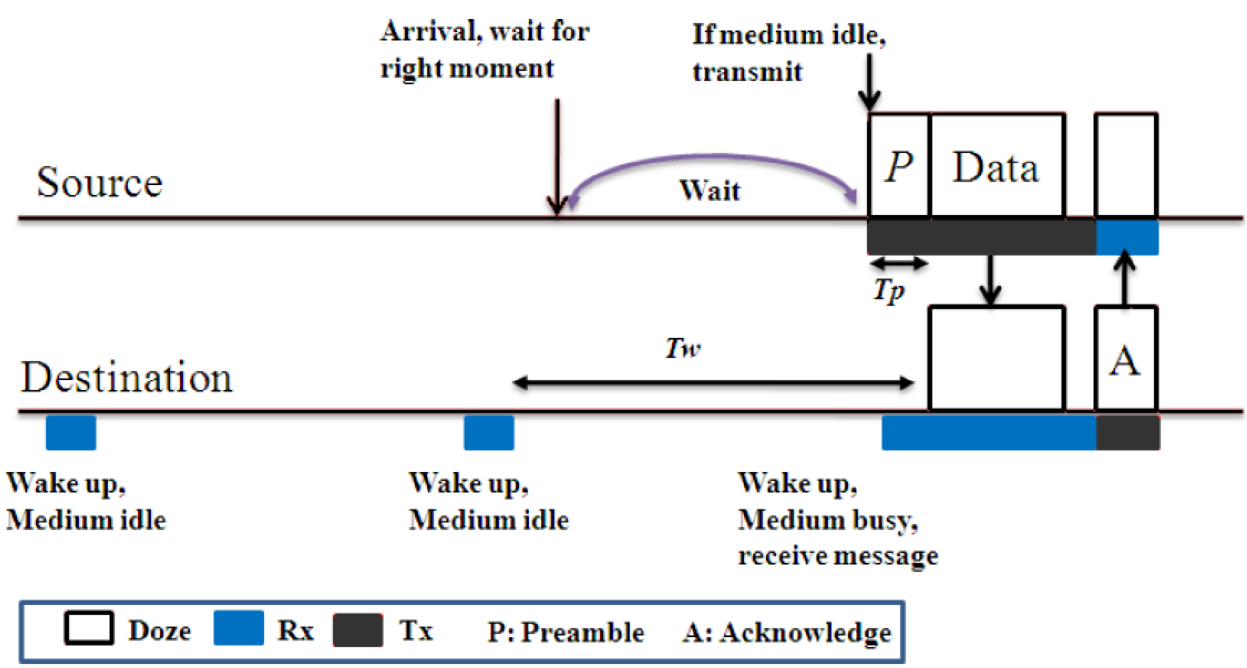


Fig.4-5[Wise MAC scheme]

4.3.4 X-MAC

- Preamble have been devided into Small stobes.
- It requires twice preamble time with extra time for arrival of acknowledgement packet for polling the channel.

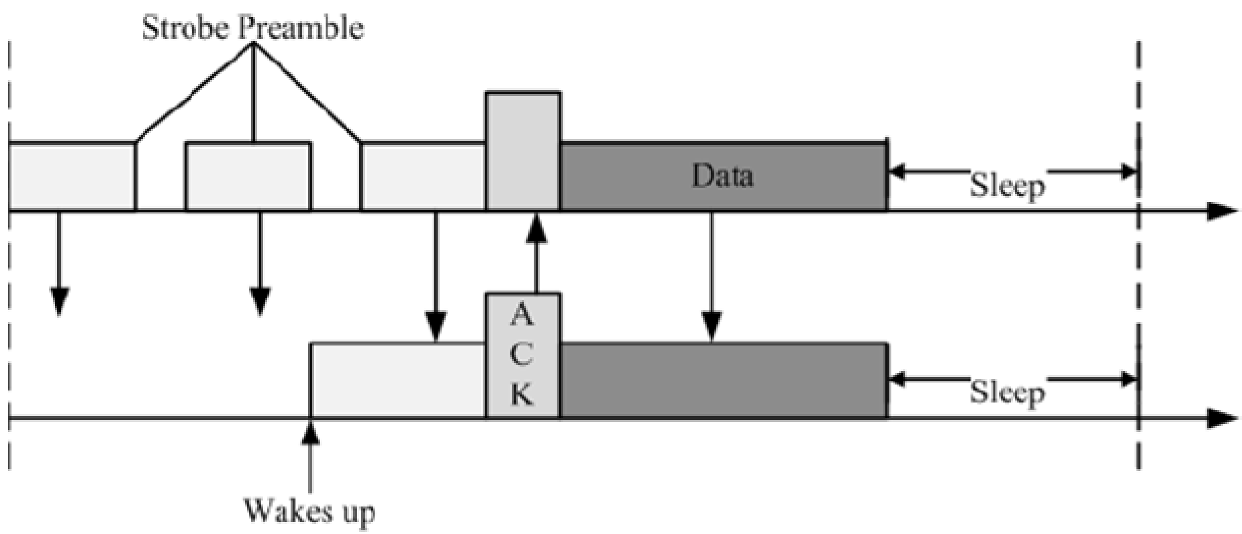


Fig.4-6[X MAC scheme]

4.4 Comparison of Existing Protocols

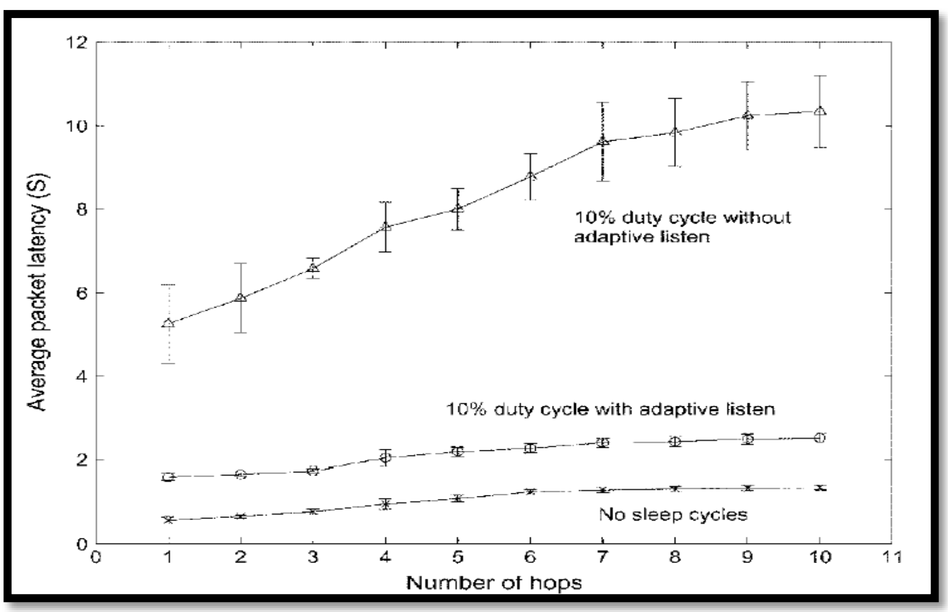


Fig. 4-7[Average latency against number of hops]

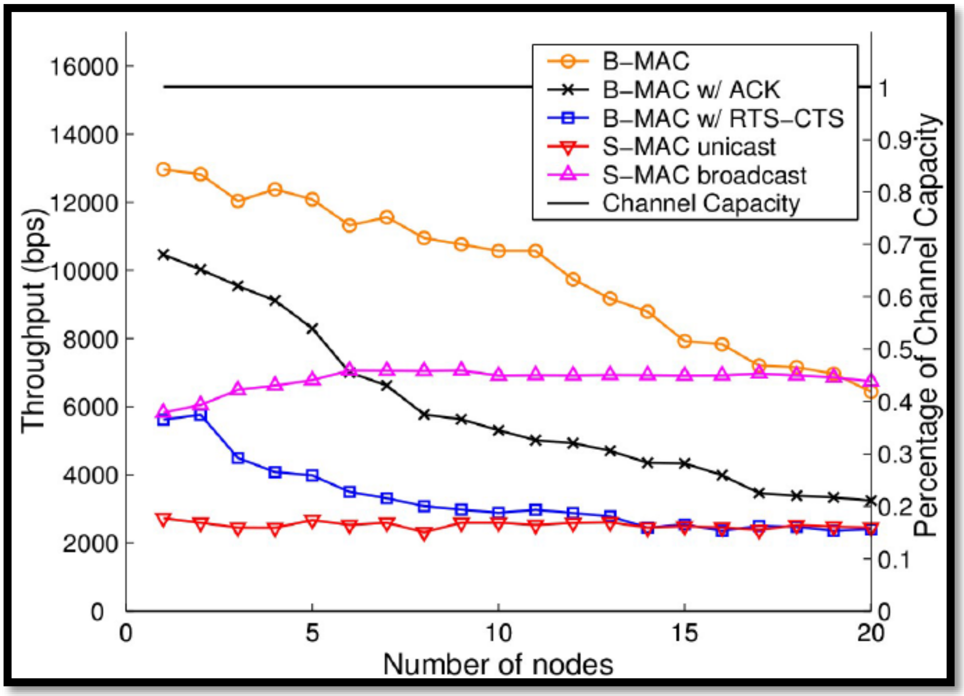


Fig. 4-8[Throughput of B-MAC and S-MAC]

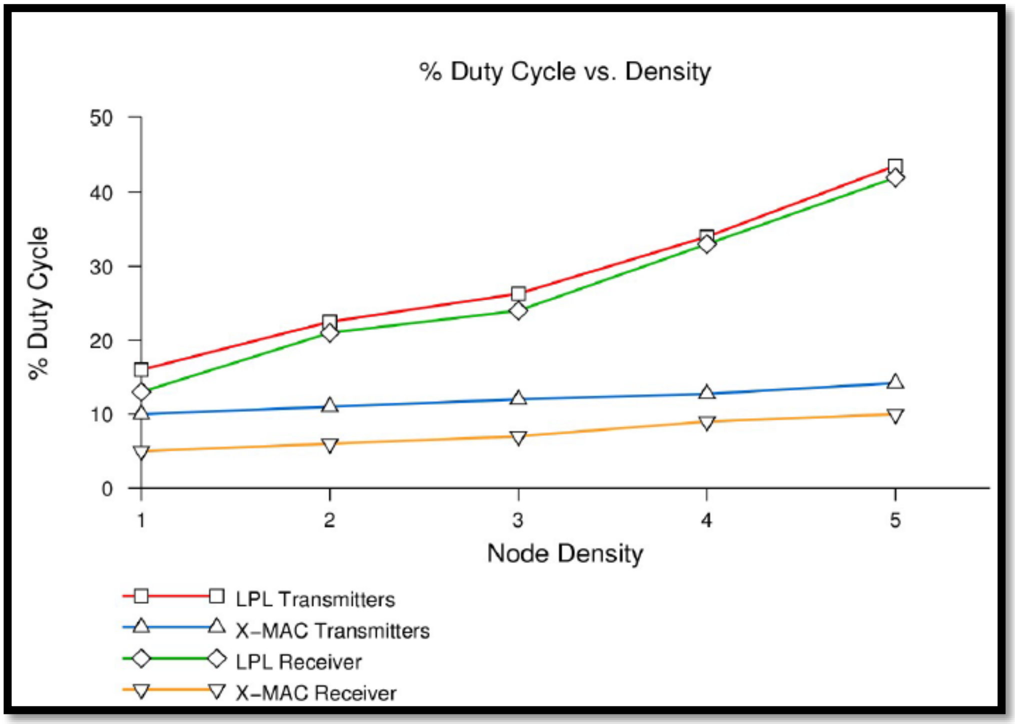


Fig. 4-9[Duty cycle vs. Density]

4.5 Conclusion

The above comparison shows there is tremendous change in throughput for both S-MAC and B-mac protocols. This is the result of unnecessary wakeup scheduling and frequent channel polling that is done by the protocols to access the channels. Hence in our opinion wireless radio can go to sleep while other sensor are awake for short period. To reduce frequent use of network, efficient protocols shoulde be devised. In [22] authors proposed two types of nodes for IEEE 802.15.4. Between these two one is only used for relaying purpose. Without adaptive listening mechanism S MAC requires more energy for data transmission and reception but compared to normal listening it is of very less difference. This is due to the heavy overhead used for continuous synchronization and free channe detection. Efficiency of network decreases if number of transmission increases. Hence MAC protocol improvement is required to overcome previously discussed issues.

Chapter 5

Proposed Energy efficient and reliable MAC protocol

5.1 Introduction

In this chapter we have described about the proposed protocol and then mathematical model has been formulated to analyze the performance of protocol. We also compare the propose protocol with the previously described protocol to get a clear vision of its performance. Here we have tried to make the scheduling and synchronization method be adaptive in nature. Here we use multi-hop method to forward the message to save the energy of sensor nodes as well as making the whole network energy efficient.

5.2 Proposed Protocol description

Our aim is to get higher throughput with minimum energy consumption, so as to make WBAN network to be more reliable.

Let the energy consumed by transceiver during one cycle:

$$E_c = E_{sl} + E_{ac}\,, \qquad (1)$$

The above expression describes the energy consumption of one cycle which equals to the total energy consumed during sleep mode (E_{sl}) and active mode (E_{ac}) by the sensor. We accentuate an adaptive approach to minimize active energy consumption by avoiding unnecessary wakeups. As a result, the proposed scheme attains energy efficiency and higher throughput.

The proposed protocol uses TDMA method and multiple hopping technique to transmit and receive data packets. It uses periodic wakeup and sleep scheduling method to reduce overhearing and idle listening. Here we consider p2p communication based mesh topology, where relay node behaves as a communicating link between source to relay node or monitoring station (MS)/hub. Total frame time (T^{FRAME}) splits into three parts according to the nature of traffic. For regular traffic, we access Contention-Free Period (CFP), For on-demand traffic or emergency requests Contention Access Period (CAP) is assigned and finally to transmit data to MS, T_{ms} time slot is provided. Again for the relay node (RN) selection procedure we use a cost function criteria, based on distance and residual energy.

Adaptive scheduling process

Nodes prior objective is to sense the changes in human health and act accordingly. Different time slots are assigned to nodes for similar work. If a node finds any critical changes then it response to the change and sends the information in its time slot. If there is no sign of significant changes within the allotted time slot, it goes to sleep mode. That means the scheduling is based on type of traffic. By this procedure, we minimize the unwanted wakeup and idle listening of other nodes. This results in saving the energy consumed due to idle listening.

Deciding the channel availability

At first Sink starts scanning for the available channel. If it finds an open channel, it sends channel packet otherwise it rescans for the available channel. This packet contains position of the sink and information regarding channel traffic. Simultaneously sender node also scans for available radio channel. Then it accesses the channel for receiving the packet after waiting for T_w duration. Otherwise, if the packet reception fails then, it jumps to other RF channel. Node sends an acknowledgment packet to sink after successful reception of packets.

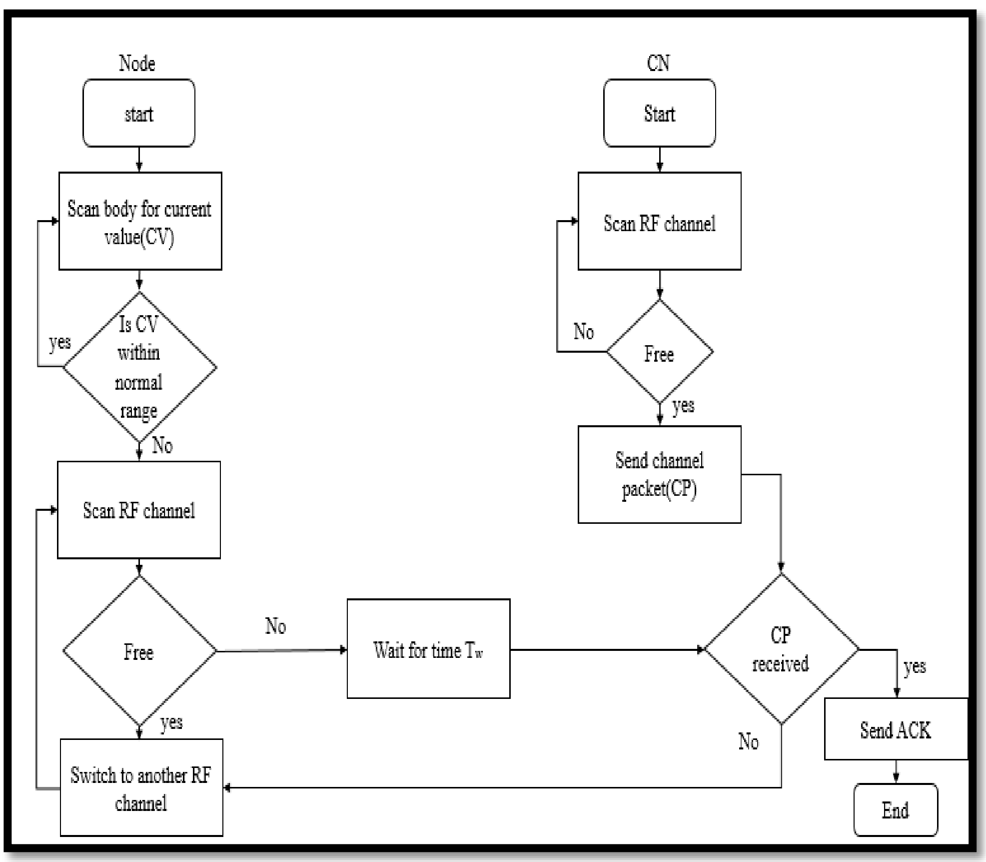


Fig.5-1[Deciding channel availability]

Node Selection and time slot allocation for sensor node

In this section, we explain the criteria and procedure for selecting proper sensor or relay node and also the time slot allocation method to all the sensor nodes. To use hopping technique, we select relay nodes based on their residual energy and distance parameter. We take a cost function into account for deciding the relay node, which depends on the distance (d_{jk}) and residual energy $(Cse_n)_i$.

$$(C.F)_i = \frac{d_{jk}}{(Cse)_i} \qquad (2)$$

After each transmission cycle consumed, we estimate the energy, and the node with minimum C.F are selected for relaying the data.

$$(Cse)_i = E - \sum_{i=1}^{r} E_i \qquad (3)$$

Here E is the energy contained by each sensor initially, and E_i is the energy used in the i^{th} round. After getting a free RF channel sensor nodes send request for time slots (TSR) to sink to transmit the required data. Then sink decides according to the data priority type and the cost function, i.e. if priority is higher, it ignores the cost function, i.e. it allows to transmit irrespective of distance and the node having C_{se} more than the threshold level. Otherwise, it considers the cost function value and gives the time slot accordingly. For nodes having same C.F value, we use guard period to avoid interference between them.

$$T_{n,n+1}^{GB} = \frac{G}{100} \times \frac{1}{2}\left(TS_n + TS_{n+1}\right) \qquad (4)$$

$$T_1^{GB} = \frac{G}{100} \times \frac{1}{2}\left(TS_1\right) \qquad (5)$$

$$T_n^{GB} = \frac{G}{100} \times \frac{1}{2}\left(TS_n\right) \qquad (6)$$

Here G is the guard band factor. It depends on average drift factor. T^{GB} is the guard time inserted before the beginning and at the end of time slot.

Synchronization Method

To use TDMA or GTS technique satisfactorily, we need proper synchronization technique which can adopt to delay or failure of data reception. In this paper, we are using drift value analysis method to give the order for synchronization. Usually there some delay may occur during the arrival of the packet which results in drift from actual arrival time. So the drift is calculated, and if the drift is more than the allowed delay period then sink sends acknowledgment for synchronization, otherwise sends simple acknowledgment. This synchronization method helps in updating time slots for future communication. This technique also allows the nodes to update the wakeup schedule for better future communication.

$$D = \min(TS_1......TS_n) \times \frac{G}{100} \tag{7}$$

Frame structure

We are considering the MAC frame structure as described in fig.5-2. The frame contains preamble, data and control packets, and it uses CAP for emergency requests. Data packet consists of information to be sent and also time slots which include both assigned time slot and guard period. Control packet is of several types.

Channel Packet: It contains unique address ID and channel information which is broadcasted after channel selection.

Time slot request packet (TSR): This packet asks for guaranteed time slot to the sink

Slot request-reply packet (SRR): Sink responses to the application and packet carries assigned time slot information.

Synchronization-Acknowledgement Packet: This packet contains the required drift value for future synchronization to the previously received data packet.

Data Request (DR): sender node sends a packet to satisfy the traffic demand for the link.

Acknowledgment packet (ACK): This packet is sent to acknowledge the reception of data packet.

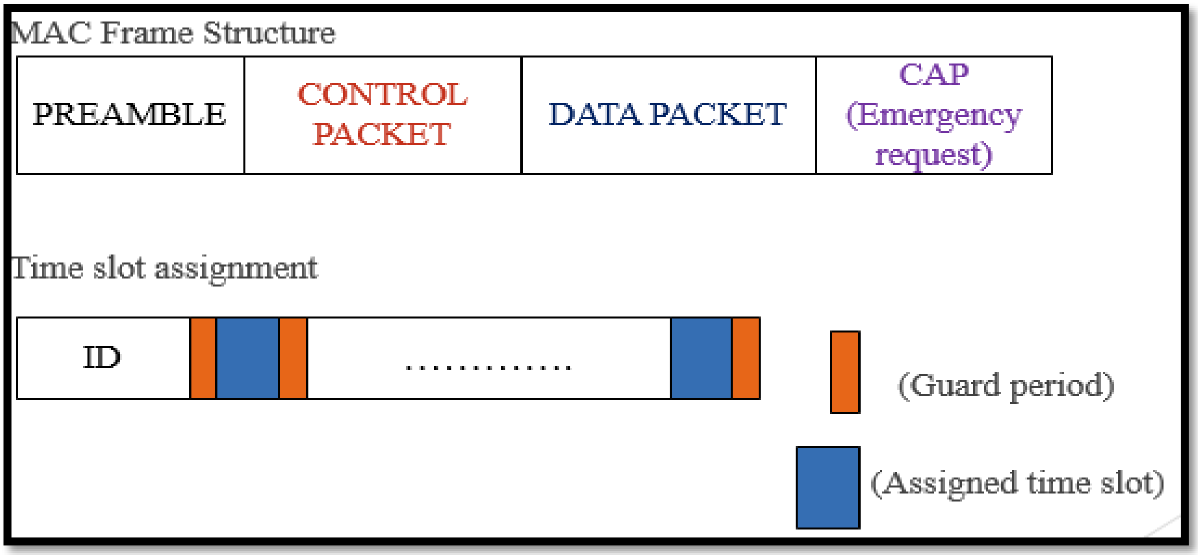


Fig. 5-2[MAC frame and time slot]

5.3 Problem Formulation And Modelling

To investigate the above protocol, a mesh topology based WBAN scenario is chosen consisting of eight nodes. Nodes are implanted around the human body. The positions are calculated and shown in fig.5-3. Here we are fixing the node positions so that the node distances will remain constant throughout the procedure.

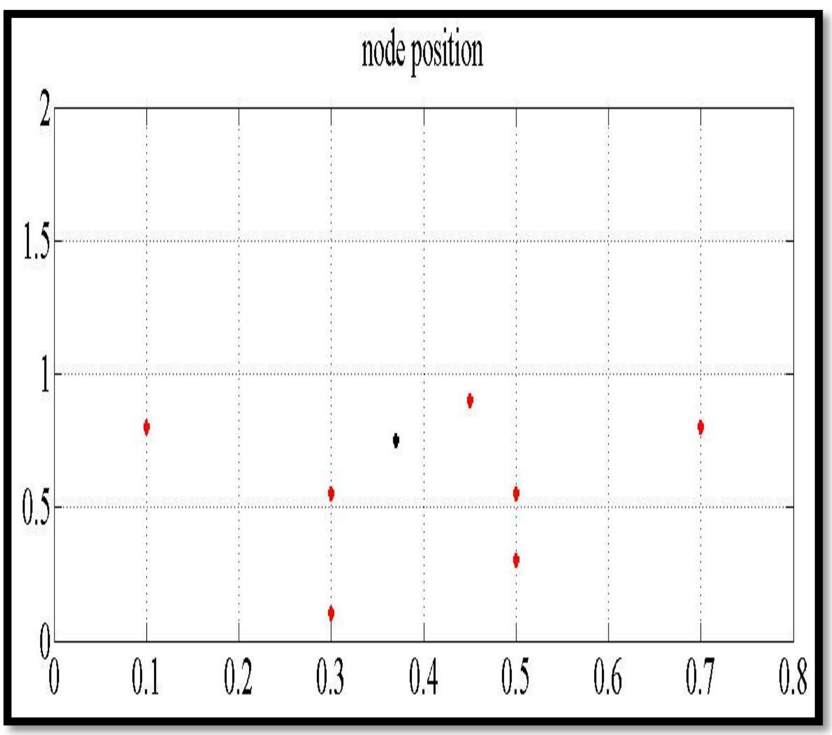


Fig.5-3[node deployment]

5.3.1 Energy Consumption Model

Energy consumption model depends on the action of each transceiver. Here we assume every transceiver is consuming constant energy at each transmission or reception of the packet. To calculate the total energy consumed, we take whole wakeup and sleep duration into account. Let the energy consumed in one cycle is E_{cy}, and E_{ac} and E_{sl} are the energy consumed in one period during active and sleep mode respectively. Hence

$$E_r = E_{ac} + E_{sl} \quad (8)$$

Total energy consumption after n cycles is

$$E = \sum_{r=1}^{n} E_r \quad (9)$$

Energy is related to the current drawn, voltage used and the period of the specified mode. For sleep mode calculation, the energy consumed is:

$$E_{sl} = V \times I_{sl} \times T_{sl} \quad (10)$$

$$T_{sl} = T_{fr} - T_{ac} \quad (11)$$

Where, T_{fr} is the total frame period, and T_{ac} is the active period of transceiver.

In active mode, the transceiver does several operations like, transmit, receive, wait for Acknowledgment and switch between active and sleep mode. Hence, we include the whole duration of the active period.

So energy consumed during active mode is:

$$E_{ac} = E_{TX} + E_{RX} + (2 \times E_{SW}) \quad (12)$$

Where, E_{SW}, E_{TX}, E_{RX} is energy consumed during switching, transmitting and receiving respectively.

Transceiver consumes energy when it jumps from active to sleep mode or vice versa. This absorbed energy is calculated as follows.

$$E_{Sw} = V \times I_{Sw} \times T_{Sw} \quad (13)$$

Energy consumed due to transmission of packets which depends on the length of the packet, time needs to deliver one byte, voltage required and current drawn during the transmission.

$$E_{TX} = V \times I_{TX} \times T_b \times K \quad (14)$$

Energy consumed during receiving is determined by following equation.

$$E_{RX} = V \times I_{RX} \times T_b \times K \tag{15}$$

We are assuming N sets of nodes which consist of all sender nodes, relay nodes, and the sink node. All nodes are communicating with each other through the wireless link of capacity W_i. Here d denotes the information processed by the sensors. The following connectivity parameter are based on the position that links between the sender and relay or sink node.

$$a_{if} = \begin{cases} 1 & \textit{sender connects with relay} \\ 0 & \textit{else} \end{cases} \tag{16}$$

$$b_{fs} = \begin{cases} 1 & \textit{relay link with sink} \\ 0 & \textit{else} \end{cases} \tag{17}$$

The above expressions describe whether the sender node connects to relay the node that means whether it is using hopping technique for conveying the information. F symbolizes the traffic flow between the nodes. We are taking the energy consumption model described in [23] to implement the protocol.

$$\min_{i \in N} \sum E_t = \sum_{i \in N} E_i + E_f \tag{18}$$

Where

$$\sum_{i \in N} E_i(Tx) = \sum_{i \in N} d_{if} a_{if} (ETx_{elec} + E_{amp} \times \eta \times D^n) \tag{19}$$

$$\sum_{i \in N} E_i(Rx) = \sum_{f \in N} d_{if} a_{if} (ERx_{elec}) \tag{20}$$

$$\sum_{i \in N} E_f(Tx) = \sum_{i \in N} C_{fs}^t (ETx_{elec} + E_{amp} \times \eta \times D^n + E_{da}) \tag{21}$$

$$\sum_{i \in N} E_f(Rx) = \sum_{f \in N} d_{if} A_{if} (ERx_{elec}) \tag{22}$$

Subjected to

$$\sum_{i \in N} d_{if} A_{if} (ETx_{elec} + E_{amp} \times \eta \times D^n) \leq E \tag{23}$$

$$\sum_{i \in N} C_{is}^t \leq W_i \tag{24}$$

$$\sum_{i \in N} C_{if}^s - \sum_{f \in N} C_{fs}^t = 0 \tag{25}$$

$$a_{if} = 1 \qquad \forall i \in N \tag{26}$$

$$b_{fs} = 1 \qquad \forall f \in N \tag{27}$$

$$C_{fs}^t \leq d_{is} b_{fs} \tag{28}$$

$$a_{if}, b_{fs} \in [0,1] \quad i, f \in N \tag{29}$$

Our primary goal is to achieve minimum energy consumption which is represented by the expression (18). The above expression is subjected to various constraints to satisfy the protocol requirement. During the active period, all the sensors consume energy according to the above expressions. That means if a node behaves as sender and transmits data then node will consume energy according to the described expression (19), and the recipient will consume according to the expression (20).

In WBAN, the sensors used have very limited energy source. So the expression (23) defines the energy capacity each node has. Equation (24) tells about the link capacity of the network on the basis of which the data packet should migrate from the source to destination. The total traffic inflow and outflow are considered equal by the expression (25). The connectivity coverage between nodes is decided by the expression (26) and (27). Total traffic flow is always less than that of data generated by the communicating nodes. This is ensured by the expressions (28).

5.3.2 Throughput Maximization Model for WBAN

As WBAN system is mostly used for patient monitoring our secondary objective is to minimize the loss of information hence maximize the throughput. In this part, we explained the methods and subjected constrains to optimize the throughput of the network so as to receive higher number of data packets. Our protocol enables the sender to send the data successfully by giving it two options to address. One is through the relay node using indirect hopping method otherwise send data directly according to priority within the given time slots. The indirect hopping technique saves energy during transmission enabling the network to live for a longer period.

Problem Formulation

Let V_{is}^{t} is the total data received at the sink node and P_i be the parameter to check the nodes having residual energy more than or equal to threshold energy E_{th}. The node stops responding if the residual energy decreases below the threshold value. Our optimization model is based on the following criteria

$$\max \sum_{i \in N} V_{is}^{t} \quad (30)$$

Successful data transmission from the source node to sink is described by the expression (30). Our motive is to maximize this for better throughput. Hence, the equation is subjected to different constrains below.

Subjected to

$$X_{ij} \in [0,1] \ \forall i, j \in S \quad (31)$$

$$E_i \geq E_{th} \quad (32)$$

$$X_{ij} \leq L_{ji} \ \ \forall i, j \in N \quad (33)$$

The uplink from sink is decided on the basis of expression (31) that means if the data packet arrives successfully with SYNC acknowledgment then there is no uplink otherwise uplink will be there for retransmission of the packet. Above described energy requirement, parameter is decided by the expression (32). In the expression, (33) L_{ij} denotes the physical link which shows that the wireless data transfer capacity (W_i) should be bounded within actual link capacity.

$$\sum_{i,j \in N} X_{ij} \le W_i \tag{34}$$

$$P_i \ge R_i \tag{35}$$

$$\sum_{(j,k)\in N} X_{jk} = \sum_{(j,k)\in N} X_{kj} \tag{36}$$

$$a_{if} = 1 \tag{37}$$

$$b_{fs} = 1 \qquad f \in N \tag{38}$$

$$a_{if}, b_{fs} \in [0,1] \qquad i, f \in N \tag{39}$$

Expression (34) signifies that the total traffic is less than the link capacity. Required data rate for communication is given to the nodes having energy more than the threshold value. This idea is conveyed by the equation (35). Equation (36) ensures that all packet is reaching the sink successfully. Finally the expressions (37) and (38) shows better connectivity to achieve high throughput.

5.4 Simulation study

First we have investigated the energy consumption difference with and without guarantee time slot allotment for baseline MAC [24] which is shown in fig.5-4. This clearly depicts that less energy consumption occurs in guaranteed time slot. Then we simulated the performance of the protocol in MATLAB and compared the result with IEEE 802.15.4 and 802.15.6 mac protocol based WBAN network

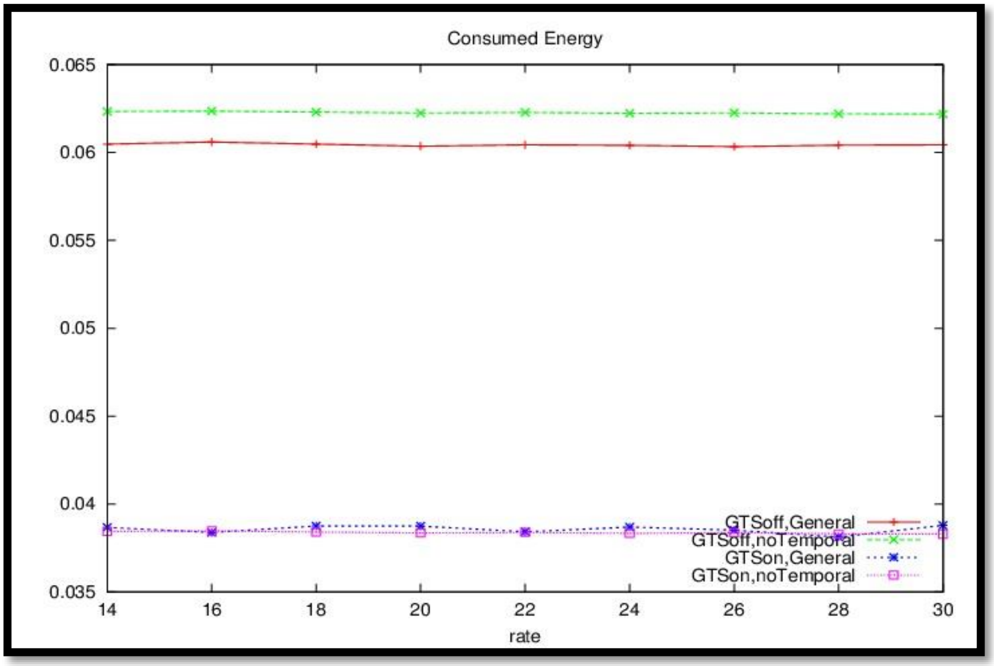


Fig. 5-4[energy consumption comparison during GTS on and off]

5.4.1 Performance metrics

We are taking following parameters into account for study and analysis of the proposed protocol.

- Network Lifetime
- Throughput
- Energy consumption

5.4.2 Radio parameter

In this section, we explain the radio model being considered for simulation. We use the radio model in [25] as s^2 can be depicted for better energy loss formulation. The radio model depends on packet length and the distance between the sender and recipient nodes. First order radio model equations are taken in 1st order and are as follows:

$$E_{Tx}(l,s) = E_{Tx-elec}(l) + E_{amp}(l,s) \quad (40)$$

$$E_{Tx}(l,s) = E_{elec} \times l + E_{amp} \times l \times s^2 \quad (41)$$

$$(Cse)_i = E - \sum_{i=1}^{r} E_i \tag{42}$$

$$E_{Rx}(l) = E_{Rx-elec} \times l \tag{43}$$

Here E_{TX} and E_{RX} represents the total energy consumption during transmission and reception respectively. For the transmission, it uses amplifier circuit to amplify the signal. Hence, transmission energy depends on E_{amp}. $E_{Tx\text{-}elec}$ and $E_{Rx\text{-}elec}$ are the energy needed for running the transmitter and receiver electronic circuit. Our protocol is used around the human body which contributes to path loss, hence path loss exponent is also considered in this radio model.

$$E_{Tx}(l,s) = E_{elec} \times l + E_{amp} \times \eta \times l \times s^n \tag{44}$$

For the simulation purpose, we choose the energy specifications of chipcon CC2420 transceiver whose operating bandwidth is 2.4GHz. The above radio equations are analyzed based on the parameter provided in Table 5-1.

The nodes are fixed in their respective positions. The figure5-4 below shows the position of nodes. The position are made fixed for easier computation.

Parameters	CC2420	Units
Current drawn(Tx)	17.4	mA
Current drawn(Rx)	19.7	mA
Current drawn(sleep)	1	Micro-A
Supply Voltage(min)	2.1	V
$E_{Tx\text{-}elec}$	96.9	nJ/bit
$E_{Rx\text{-}elec}$	172.8	nJ/bit
E_{amp}	2.71e-7	j/b

Table5-1[CC2420 radio parameters]

5.4.3 Simulation results and analysis of MAC protocols

In this section we are trying to compare and analyze behavior of the proposed protocol with the existing protocols, described in the previous section.

In [27] [26] authors have provided some realistic data on arrival rate for various BNs on the basis of emergency- traffic and for normal/on-demand traffic. We have constructed the wakeup table for a real scenario on patient monitoring keeping these as reference values.

P_{tx}	Power required for Tx
P_{rx}	Power required for Rx
T_{data}	Time required for data packet transmission
T_b	Time required for beacon packet transmission
T_{ack}	Time required for Ack packet transmission
P_{active}	Power consumption in active state
P_t	Power required for switching between states
T_t	Time required for switching between states
P_{twbn}	Power required to transmit low power wakeup packet
P_{rwbn}	Power required to receive power wakeup packet
T_{wbn}	Time required to send low power wakeup packet
R	Data rate of the radio
T_{cca}	Time required for CCA or carrier sensing
P_{sl}	Power consumed in sleep state
T_{wk}	Interval between preamble/beacon samplings
T_p	Preamble duration
T	Total time duration

Table. 5-2[variable explanation for MAC protocol simulation]

P_{tx}	27mW	P_{active}	0.005mW	L_{beacon}	10bytes
P_{rx}	1.8mW	R	25kb/s	L_{ack}	10bytes
T_{data}	16ms	L_{data}	50bytes	L_{wup}	8bytes
T_{ack}	3.2ms	P_{tr}	0.004mW	N	10
T_b	3.2ms	T_{tr}	0.8ms		
P_{tx}	14.39mW	T_{cca}	3ms		
T_t	0.4ms	P_{sl}	0.004mW		

Table. 5-3[common input parameter]

Proposed MAC	WisseMAC	X MAC
P_{twbn} 1.4mW	T_{wk} 400ms	T_{wkrx} 43.35ms
P_{rwbn} 0.4mW	T_p 20ms	T_p 2.41ms
T_{wbn} 2.56ms	**B MAC**	N_{probe} 3.8ms
P_{twack} 1.4mW	T_{wk} 400ms	
T_{wk} 5.12ms	T_p 86.7ms	

Table. 5-4[specific parameter for MAC]

For calculation simplicity, we assume the average emergency traffic for the network as 0.00005. We have simulated and analyzed our proposed MAC against different existing protocol such as WiseMAC, X MAC, Zigbee, etc.. The simulation parameters are calculated for proposed protocol and and for others it has been taken as per the tables, reffered from [28- 30, and 31].To analyze the total power consumption we consider the average power consumed during following process. Such as:

- Average wakeup power
- Average transmission power
- Average receive power
- Average power consumed due to overhearing

Equation to calculate power consumption:

$$P_{avg} = P_{wk-avg} + P_{tx-avg} + P_{rx-avg} + P_{ov-avg} \qquad (45)$$

Where,

$$P_{wk-avg} = \frac{(P_{rwbn} + T_{wbn}) + (P_{twack} + T_{twack})}{T} \qquad (46)$$

$$P_{tx-avg} = P_{tx} \times \frac{T_{data}}{T} \qquad (47)$$

$$P_{rx-avg} = P_{rx} \times \frac{T_b + T_{ack}}{T} \qquad (48)$$

$$P_{ov} = P_{rwbn} \times \frac{T_{wbn}}{T} \times (N-1) \qquad (49)$$

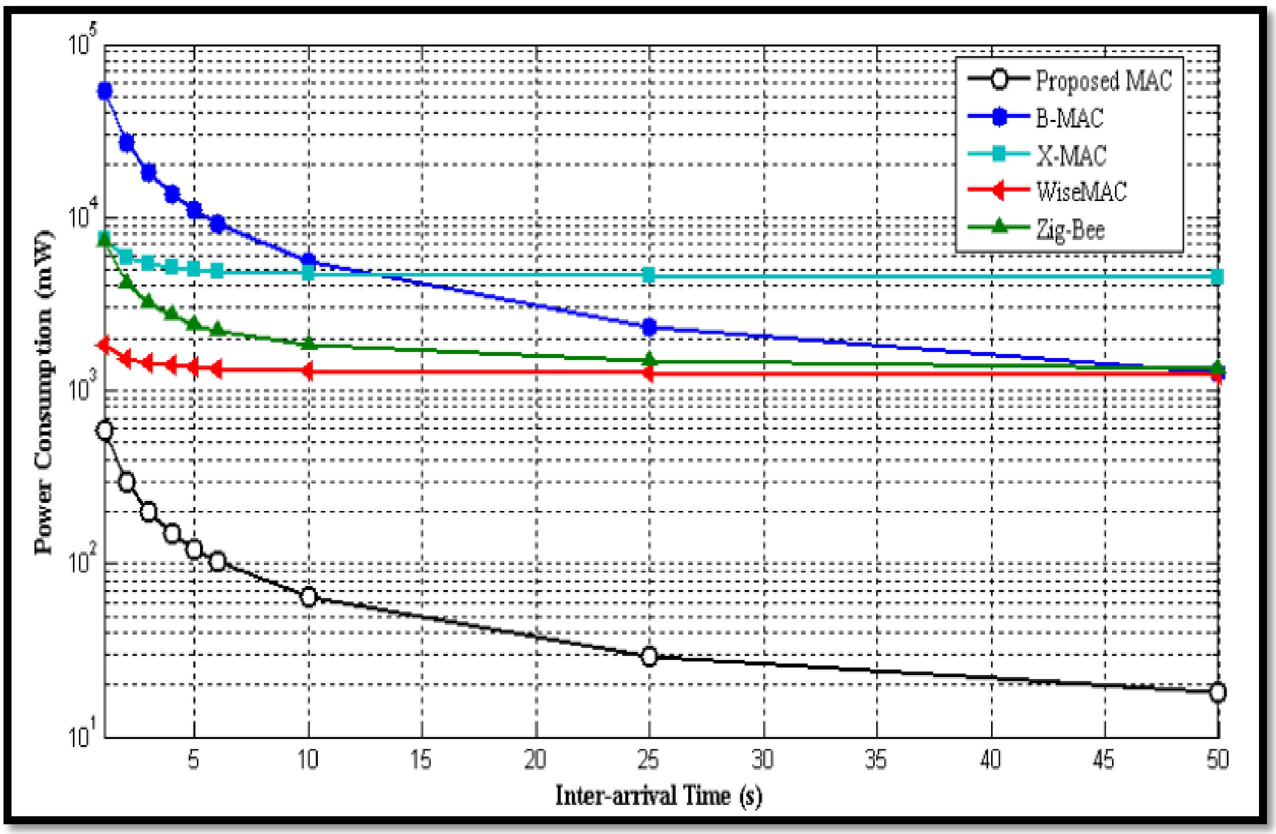


Fig. 5-5[power consumption comparison w.r.t inter-arrival time]

Figure5-5 depicts the behavior of pwer consumption for the proposed protocol. Proposed mac performance improves by the use of adaptive nature for wake up periods and multi hopping process. This happens as in our model, we are lessening the unnecessary wakeups sensors need not consume energy for idle listening whereas multiple hopping causes saving of energy for data transmission. As Overhearing is also a cause of energy degradation, here the proposed protocol saves power by removing the idle listening and reducing the overheads.

$$T_{sl} = T - (T_{tr} + T_b + 2T_t + T_{data} + T_{ack}) \quad (50)$$

Delay is measured through the following equation and then analyzed against other protocols.

$$D_{pr} = T_{ack} + T_{tr} + T_b + 2T_t + T_{data} + T_{wack} + T_{wbn} \quad (51)$$

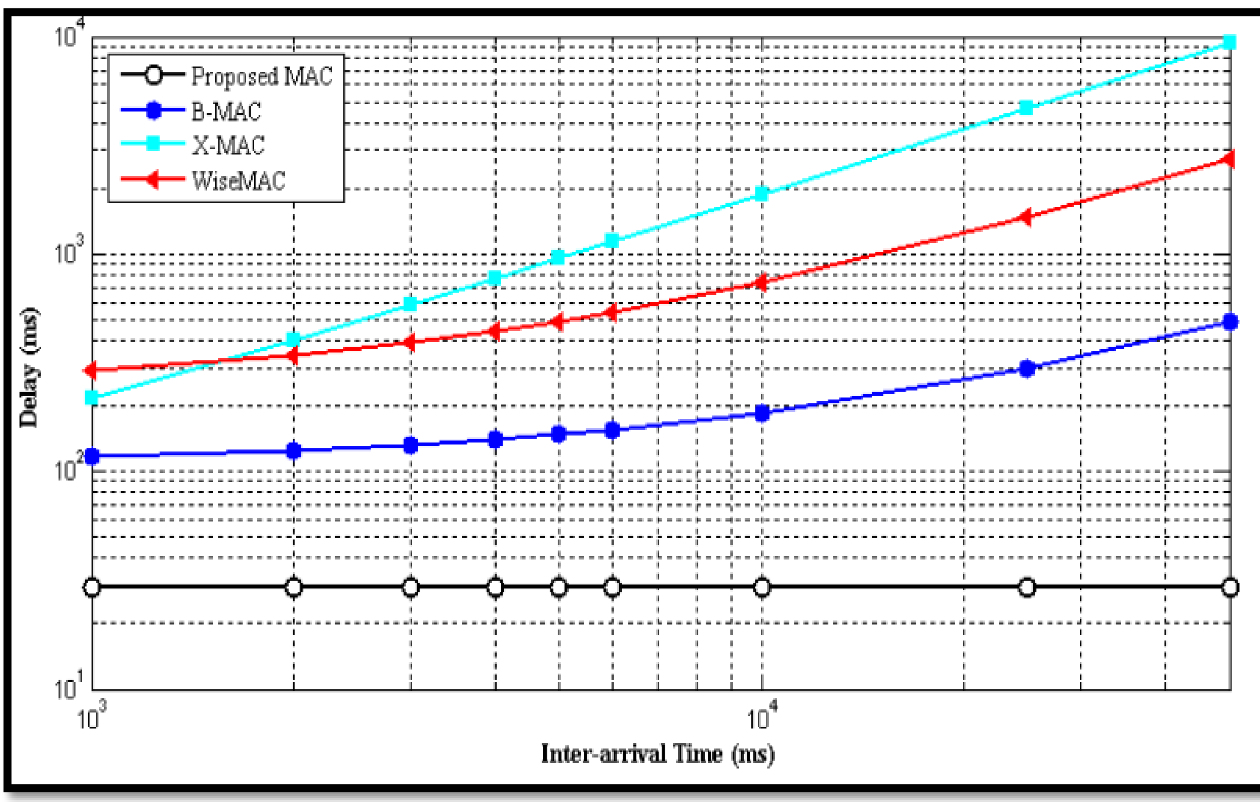


Fig. 5-6[delay with respect to. inter-arrival of packets]

The figure 5-6 shows comparison of delay time From above results it is clear that proposed scheme outperform others MACs. It is because delay is remaining fairly constant throughout. This is because we are using TDMA based method to avoid wakeup-delay and hopping method to reduce transmission path loss delay. In BMAC protocol, to transfer packets from source to sink it needs extra time as the entire preamble must be sent to receiver though it is already awake. In X-MAC, due to extra strobe preamble delay time increases.

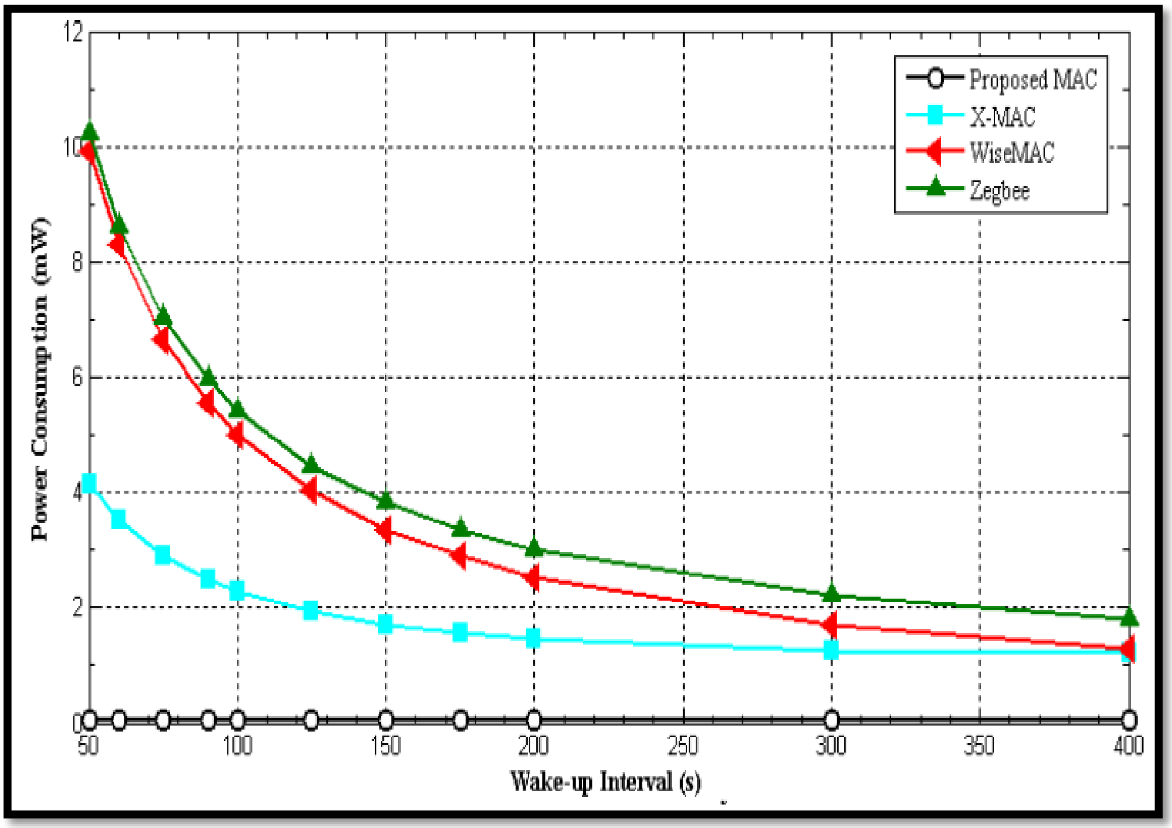


Fig. 5-7[power consumption comparison according to wake-up interval]

Wake up interval is an enemy of duty cycle based protocols like X-MAC, WiseMAC, and ZigBee as wakeup has to be adjusted for optimal performance. Since our protocol hardly needs any wakeup adjustments except emergency request, the power requirement is very less compared to other protocols. As our protocol behaves for on demand traffic mostly, wakeup intervals are controlled by coordinator node which concludes on demand schemes perform better than duty cycled scheme.

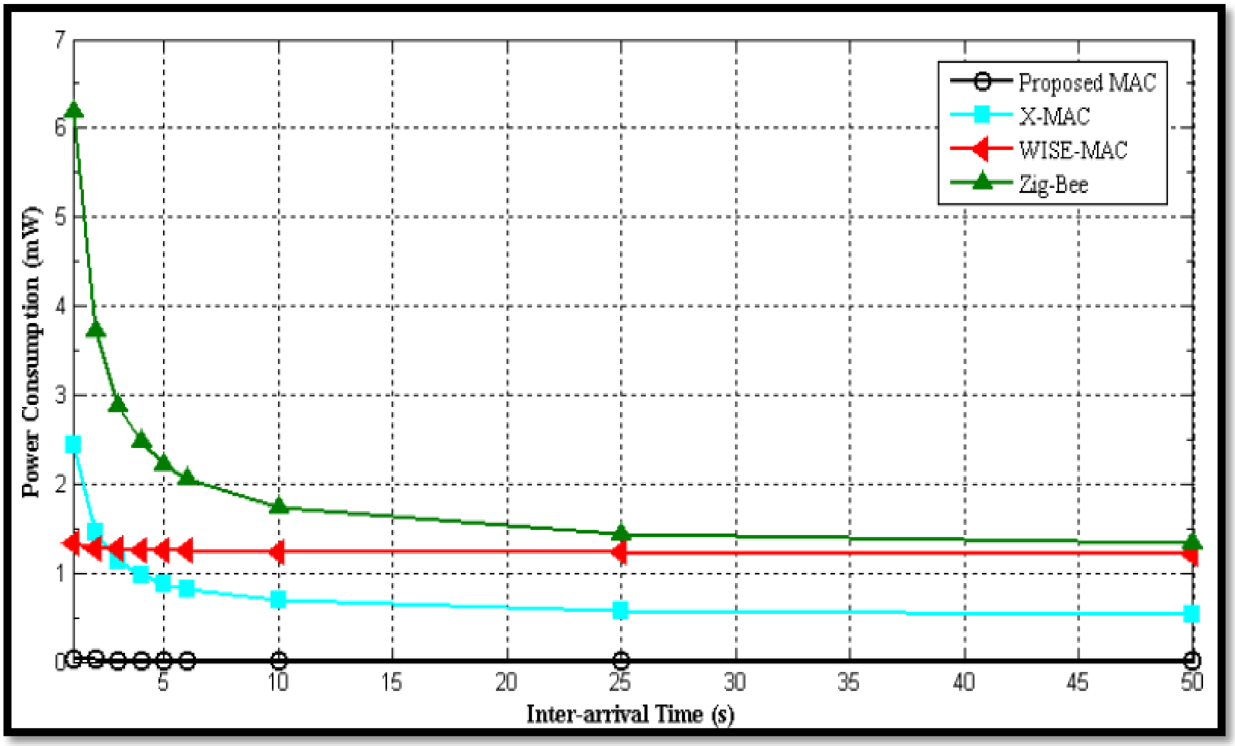


Fig. 5-8[Power consumption vs. inter arrival time]

The above fig shows that proposed protocol behaves more power efficient as it reduces energy needed for overhead packet transmission. As it is a TDMA based protocol it does not have heavy overhead packets. It needs only node identifier (NID) for better hopping transmission..

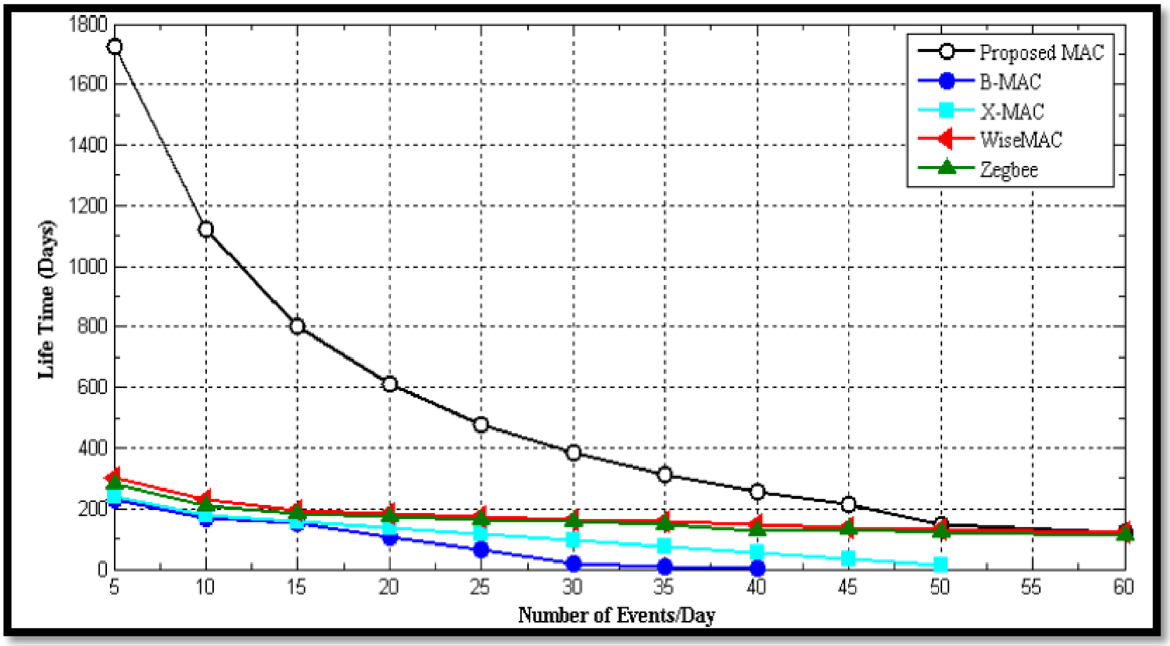


Fig. 5-9[life time vs. number of events]

Figure5-9 gives comparison on network lifetime with respect to events per day. It shows significant increase in lifetime of network. There is a huge difference in the starting due to less events per day as a result of less switching between states (active-sleep-active) which avoids energy wastage. Hence, proposed protocol achieves higher network lifespan as sleep time of sensor nodes are minimized. The lifetime of network decreases with increase in events per day due to gradual increase in traffic. Still the proposed MAC shows better performance than other MACs as they waste energy due to unnecessary channel assessment and wakeups.

We have compared the analysis result with simulated data. The comparison has small difference due to the randomness of emergency traffic.

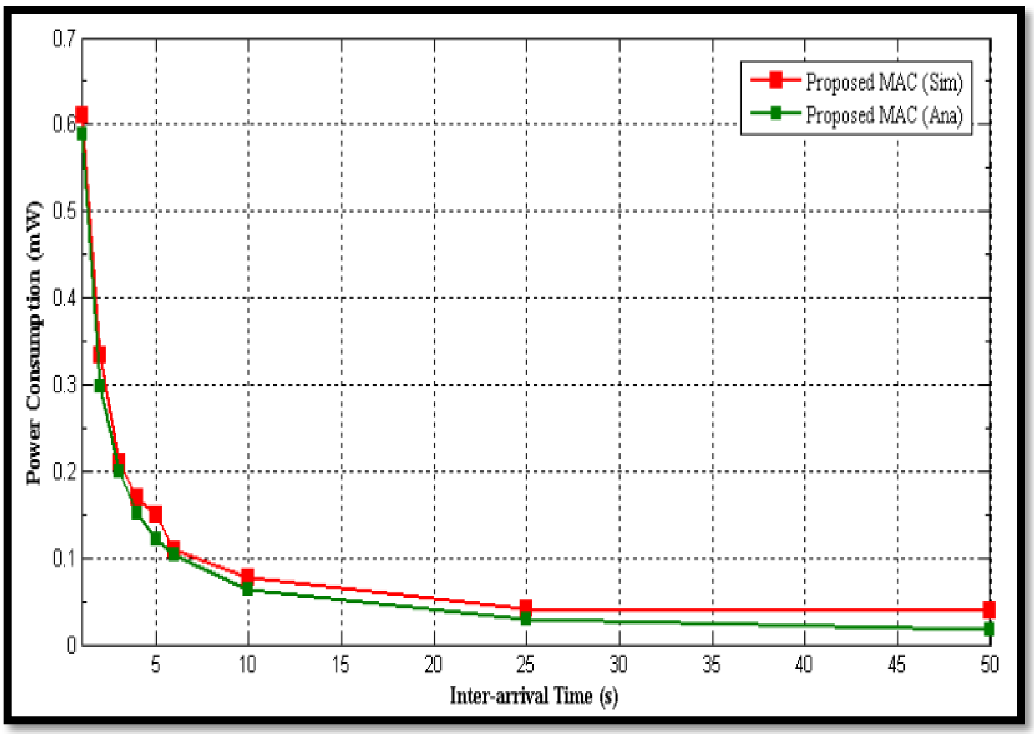


Fig. 5-10[Comparison of analysis against simulated data]

5.4.4 WBAN system model simulation and analysis

In this section we are comparing and analyzing the total WBAN network based on performance metrics discussed earlier. We are using the following system model of node allignment to analyze the WBAN network behavior.

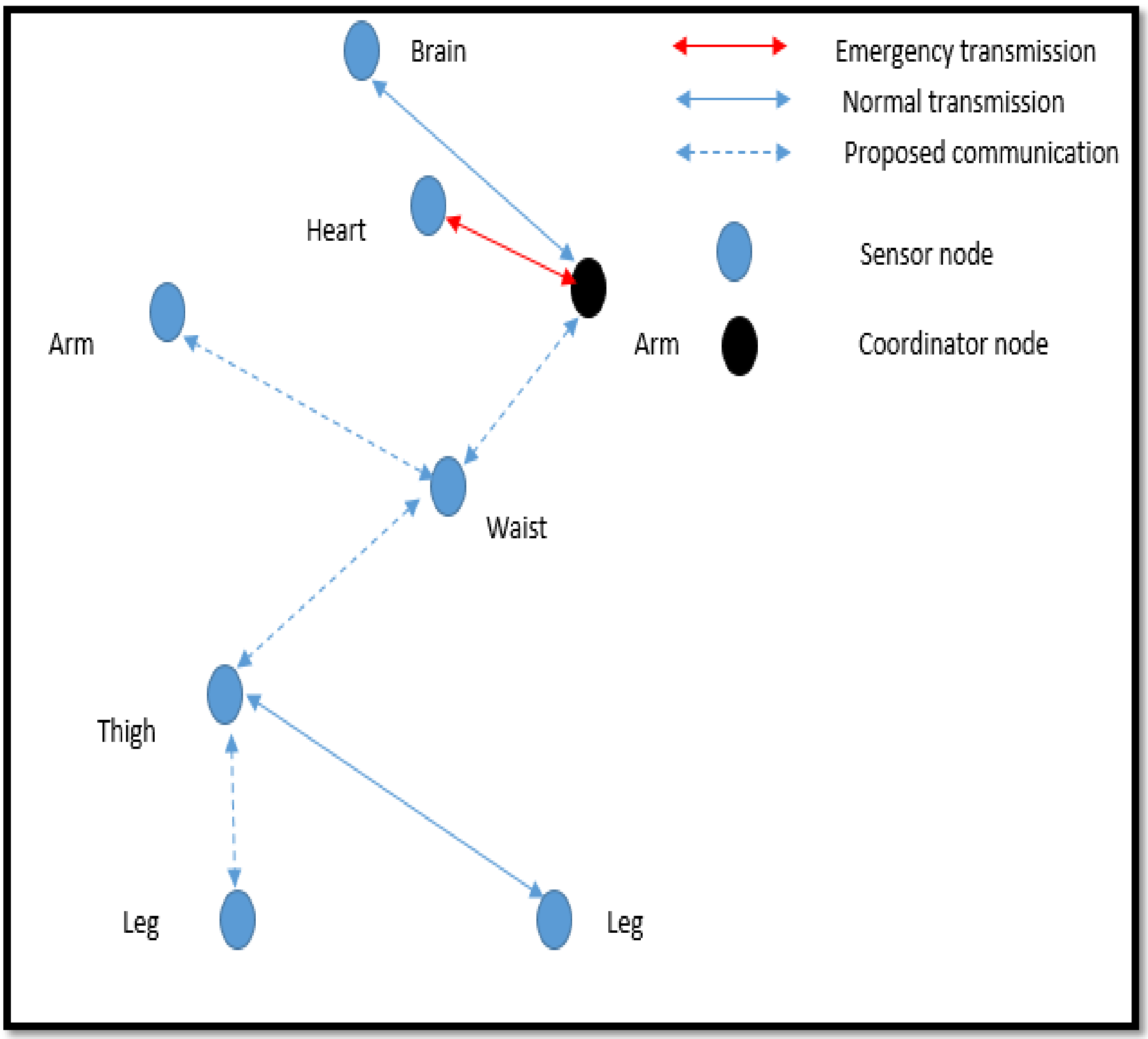


Fig. 5-11[system model for analysis]

A. Network Lifetime

From the table below, up to 4000 round all the node are working perfectly for proposed protocol whereas 802.15.4 protocol sacrifices three nodes due to extra energy spend for transmitting more overhead packets. Then at about 6600 round four nodes die out in our proposed protocol whereas for 802.15.6 almost six node die.

Round	802.15.4	802.15.6	Proposed-MAC
4000	3	0	0
6600	3	6	4
8000	8	8	5

Table. 5-5 [No. of dead nodes]

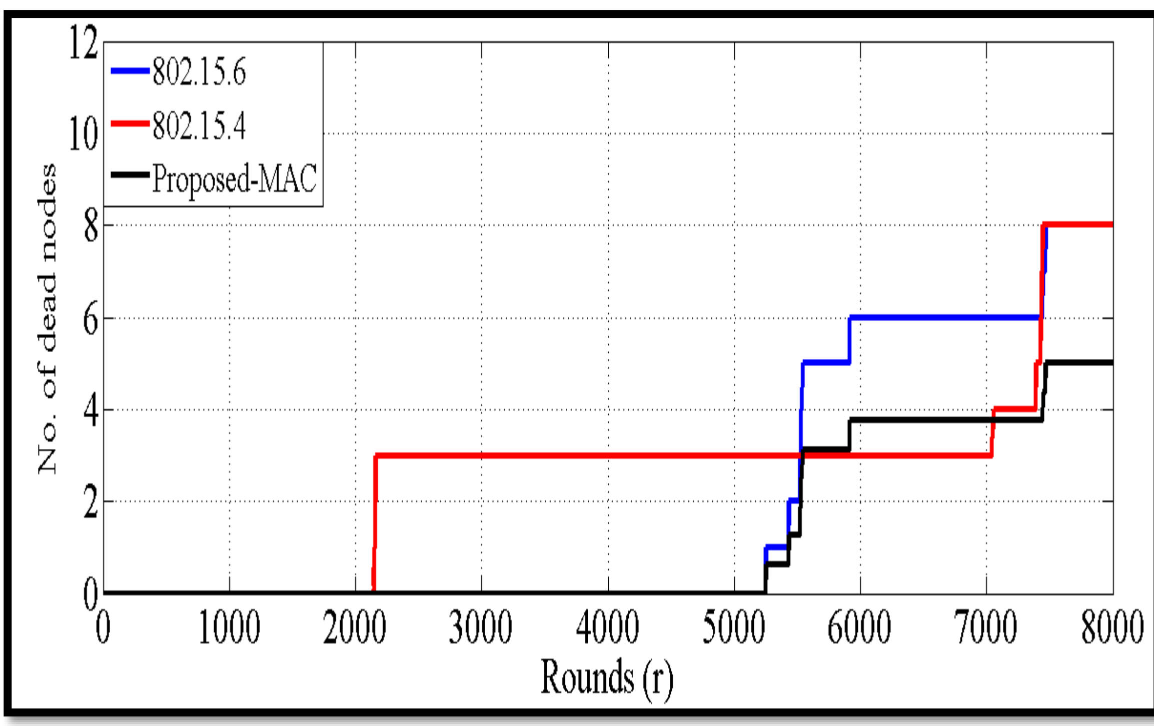


Fig. 5-12[Number of dead nodes]

This is due to lack of synchronization which also causes collision of packets contributing to resend of packets more times compared to proposed protocol. Eventually at 8000_{th} round our proposed protocol has three nodes working properly whereas in other networks using 802.15.4 and 802.15.6 all nodes have died out. This shows the life span of network increases with our proposed protocol.

B. Throughput

As WBAN conveys critical and crucial data regarding human health, it requires a protocol that is able to carry that message successfully to the receiver end.

Rounds	802.15.4	802.15.6	Proposed-MAC
4000	10000	11000	13000
6000	13000	26000	33000
8000	19000	29000	35000

Table. 5-6 [Received packets at sink]

The above throughput comparison table gives an idea on amount of successful packet transmission. This shows that the proposed protocol has received much higher number of packets than other networks communicating through 802.15.4 and 802.15.6 protocol. This is the result of better scheduling mechanism adapted here which is flexible to the delay of any packet reception time period. The figure below shows the comparison of packet received at the destination by all the protocols. As the throughput of the proposed protocol is the highest among all, it shows great reliability in successful data transmission.

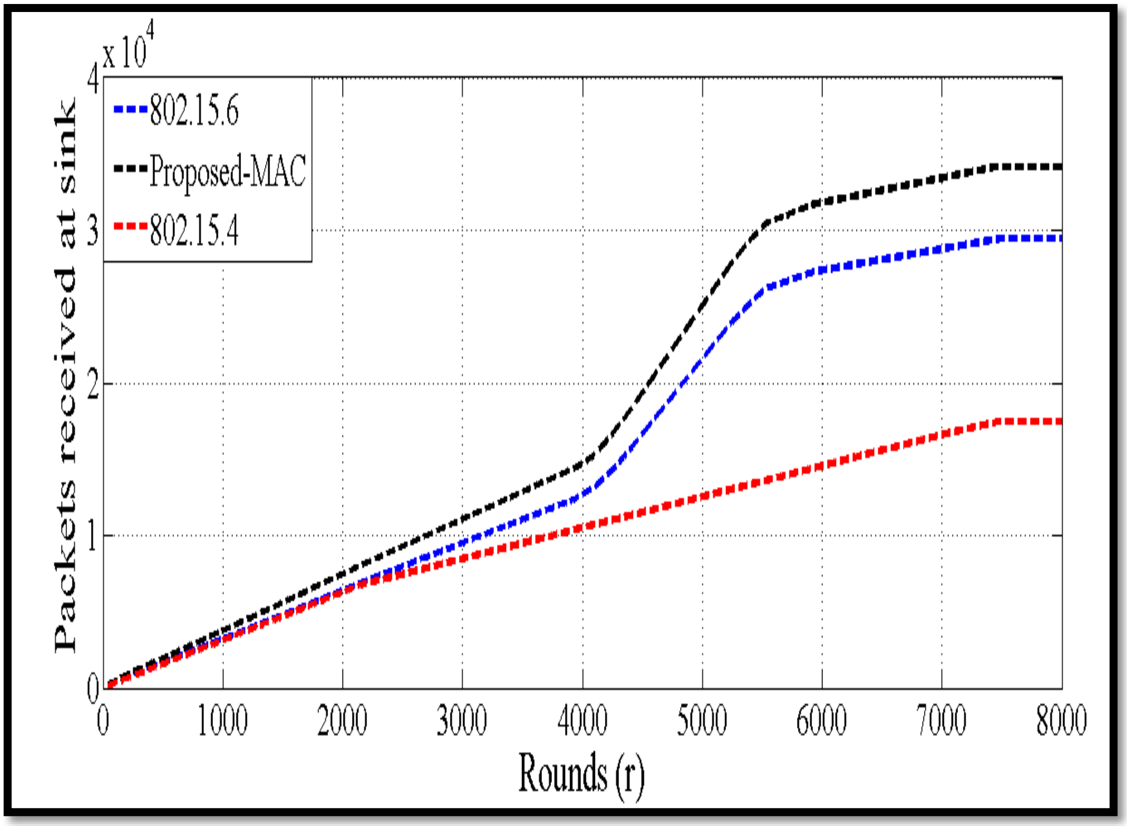


Fig. 5-13[packets received at sink at each round]

C. Energy consumption

We are comparing the average energy consumption of three different network using 802.15.4, 802.15.6 and our proposed protocol according to packet error rate. The table below gives a view that our proposed protocol very slight increase in energy consumption with respect to increase in packet error rate whereas other two protocols consume higher amount of energy. This is due to the intelligent selection of relaying nodes for hopping that has done in the proposed protocol.

Packet error rate (%)	802.15.4	802.15.6	Proposed-MAC
6	7.53	7.43	7.41
14	7.58	7.45	7.41
20	7.65	7.47	7.42

Table. 5-7 [Energy consumption(mJ) table]

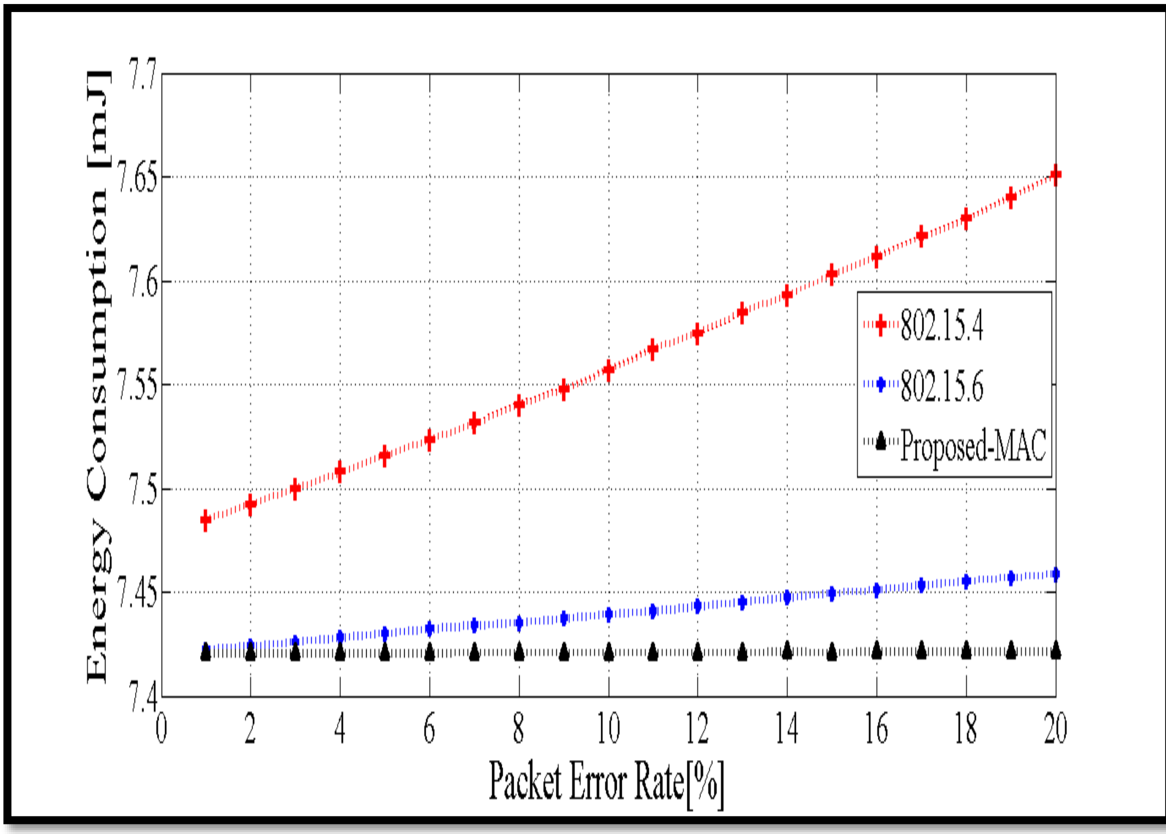


Fig. 5-14[energy consumption w.r.t packet error rate]

The figure depicts that for same packet error rate the energy consumption in our proposed protocol is lesser than 802.15.4 and 802.15.6. In IEEE 802.15.4 the nodes spend more energy due to transmission of extra overhead packets and task group 6 uses protocol that has higher collision rate without any synchronization technique. Task group 6 also uses single hop method for data communication. These cause excessive energy consumption. Whereas our proposed protocol uses multihop relaying technique with better synchronization that results in less energy consumption.

Chapter 6

Conclusion and Future Scope of Research

6.1 Conclusion

We have simulated the protocol five times and in each time we estimate the consumption rate for 8000 cycles. Then finally we have taken the average consumption and compared it, which gives the idea of received packets at sink after completion of the transmission, which also describes the throughput and reliability of the channel. The proposed new price function to pick relay node for hopping approach performs a key function to stabilize the energy consumption equally for every sensor nodes. A new relaying node is chosen in each round on the basis of estimated cost function. From the above simulations it is analyzed that the proposed protocol gets higher stability period. This is obtained, by the proper selection of new relay node in each round. As a result, each node eventually consumes almost equal energy in each round and hence lifespan of nodes become almost equal. Whereas 802.15.6 uses single hop direct transmission causing higher energy consumption due to path loss and 802.15.4 uses unnecessary wakeup period for idle listening and CCA which results in more consumption. Hence, nodes die earlier than that of the proposed protocol. Our proposed protocol gets higher throughput than task group 4 (802.15.4) and 802.15.6. The proposed protocol uses adaptive synchronization and scheduling process to adapt the timeslot according to clock drift that causes successful reception and for transmitting, we use nearest relay node so as minimize energy loss and path loss to reduce packet loss. Hence, eventually we are getting better throughput results than that of compared existing protocols. The number of nodes that are alive at the end of the simulation are more compared to other protocol which also shows the proof of minimal energy consumption by the nodes in our proposed protocol. This is the result of the adaptive transmission method used in the above scheme which has adaptive synchronization and time slot allocation mechanism.

Eventually from the above results we conclude that our defined protocol has about 33% lower energy consumption which leads to better performance as nodes lifetime is enhanced which results in longer communication duration. We make the protocol adaptive towards wakeup scheduling and hopping mechanism which helps in better energy usage of nodes.

6.2 Limitation and Future Scope

We have kept the node position constant in this work for easy analysis whereas in real time the nodes are movable with the human movement which may leads to greater transmission loss and signal fading causing decrease in reliability. Hence in future protocol can be made flexible by including timely varying node characteristics like distance, angle etc.

WBAN works within very short range i.e. 10m as per IEEE standard. The network behavior under large area, where cluster of nodes come to picture has not been investigated till date. So proper communication protocols can be designed to overcome the coverage shortcoming of WBAN network.

Also QoS of BAN varies for different applications. For example in medical field QoS parameter is throughput and energy consumption of transmission whereas for military purpose data security and reliability are most important QoS parameter. Hence to satisfy these many QoS parameters within one network a single protocol becomes very stiff. That's why there can be use of genetic algorithm which will be able to decide correct communication protocol according to application requirements.

BIBLIOGRAPHY

[1] Li, M., Li, Z., & Vasilakos, A. V., A survey on topology control in wireless sensor networks: taxonomy, comparative study, and open issues. Proceedings of the IEEE, 101 (2013), pp. 2538–2557, doi:10.1109/JPROC.2013.2257631.

[2] Sheng, Z., Yang, S., Yu, Y., & Vasilakos, A. V., A survey on the ietf protocol suite for the internet of things: Standards, challenges, and opportunities. IEEE Wireless Communications, 20 (2013), pp. 91–98, doi:10.1109/MWC.2013.6704479.

[3] Javaid, N., Hayat, S., Shakir, M., & Khan, M. A.. Energy efficient MAC protocols in wireless body area sensor networks— A survey. Journal of Basic Applied Scientific Research, abs/1303.2072 (2013), pp. 1–17.

[4] Yao, Y., Cao, Q., & Vasilakos, A. V. EDAL: An energyefficient, delay-aware, and lifetime-balancing data collection protocol for wireless sensor networks. IEEE 10th international conference on mobile ad-hoc and sensor systems (2013) pp. doi:182–190, 10.1109/MASS.2013.44.

[5] Yao, Y., Cao, Q., & Vasilakos, A. V., EDAL: An energyefficient, delay-aware, and lifetime-balancing data collection protocol for heterogeneous wireless sensor networks. IEEE/ACM Transactions on Networking, (2014) doi:10.1109/TNET.2014.2306592.

[6] O. Omeni, A. C. W. Wong, A. J. Burdett, and C. Toumazou, "Energy efficient medium access protocol for wireless medical body area sensor networks," IEEE Transactions on Biomedical Circuits and Systems, vol. 2(2008), no. 4, pp. 251–259, doi:10.1109/TBCAS.2008.2003431.

[7] N. F. Timmons and W. G. Scanlon, "An adaptive energy efficient MAC protocol for the medical body area network," in Proceedings of the 1st International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace and Electronic Systems Technology, Wireless (VITAE'09), (2009), pp. 587–593, doi:10.1109/WIRELESSVITAE.2009.5172512

[8] A. Boulis and Y. Tselishchev, "Contention vs. polling: A study in body area networks mac design," in Proceedings of the Fifth International Conference on Body Area Networks, ser. BodyNets, (2010), pp. 98–104. doi:10.1145/2221924.2221944.

[9] Y. Tselishchev, L. Libman, and A. Boulis, "Reducing transmission losses in body area networks using variable tdma scheduling," in 2011 IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks (WoWMoM), (2011), pp. 1–10, doi: 10.1109/WoWMoM.2011.5986465.

[10] S. Ullah, B. Shen, S.M. Riazul Islam, P. Khan, S. Saleem, andK.S. Kwak, "A study of MAC protocols for WBANs," Sensors, vol.10, (2010), pp. 128–145, doi:10.3390/s100100128

[11] Maskooki, Arash, et al. "Opportunistic routing for body area network." proceeding of IEEE Consumer Communications and Networking Conference (CCNC), (2011), pp. 1-6.

[12] 802.15.6-2012 - IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks. 29 February 2012. pp : 1-271.

[13] IEEE 802.15 WPAN Task Group 6 BAN: http://www.ieee802.org/15/pub/TG6.html

[14] Otto C., Milenkovic A., Sanders C. & Jovanov E., System architecture of a wireless body area sensor network for ubiquitous health monitoring. Journal of Mobile Multimedia, 1(2006) pp. 307–326.

[15] IEEE Std 802.15.6. 2012. IEEE Standard for local and metropolitan area networks Part 15.6: Wireless Body Area Networks. IEEE Computer Society. Available from: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6161600.

[16] Thapa, A. & Shin, S., QoS provisioning in Wireless Body Area Network: A review of MAC Aspect. KSII Transaction on Internet and Information systems. Vol. 6 (2012), pp. 1267-1285.

[17] Zhang, Y., & Dolmans, G., 2010. Priority-guaranteed MAC protocol for emerging wireless body area network. Institut Télécom and Springer – Verlag, 66 (2011), pp. 229-241.

[18] Li, H.M.; Tan, J.D. An ultra-low-power medium access control protocol for Body Sensor Network. In Proceedings of 27th Annual International Conference of the Engineering in Medicine and Biology Society, Shanghai, China, 2005; pp. 2451-2454.

[19] Ullah, S.; Kwak, D.; Lee, C.; Lee, H.; Kwak, K.S. Numerical Analysis of CSMA/CA for Pattern-Based WBAN System. In Proceedings of Biomedical Engineering and Informatics, 2009 pp. 1-3.

[20] El-Hoiydi, A.; Decotignie, J.D. WiseMAC: An ultra low power MAC protocol for the downlink of infrastructure wireless sensor networks. In Proceedings of the Ninth IEEE Symposium on Computers and Communication, ISCC'04, Alexandria, Egypt, 6(2004); pp. 244-251.

[21] Ye. W.; Estrin, H.J. An energy-efficient MAC protocol for wireless sensor networks. In Proceedings of Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies, Miami, FL, USA, 3 (2002); pp. 1567-1576.

[22] J.-S. Lee, "Performance Evaluation of IEEE 802.15.4 for Low-Rate Wireless Personal Area Networks", IEEE Transactions on Consumer Electronics, Vol. 52 (2006), pp. 742-749.

[23] J. Elias and A. Mehaoua, "Energy-aware topology design for wireless body area networks," in IEEE International Conference on Communications , (2012), pp. 3409–3410.

[24] "Mac and security baseline proposal," in IEEE 802.15 Documents, Document no. 196, rev.2, March 2010.

[25] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference on, 2 (2000) pp. 1-10.

[26] JY Khan, MR Yuce, F Karami, Performance evaluation of a wireless body area sensor network for remote patient monitoring, in 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS 2008, Vancouver, Canada, 6 (2008) pp. 1266–1269, doi:10.1109/IEMBS.2008.4649394.

[27] HC Keong, MR Yuce, Analysis of a multi-access scheme and asynchronous transmit-only UWB for wireless body area networks, in 31st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'09), Minnesota, USA, 101(2009) pp. 6906–6909.

[28] A El-Hoiydi, J-D Decotignie, WiseMAC: an ultra low power MAC protocol for the downlink of infrastructure wireless sensor networks, in Proceedings Ninth International Symposium on Computers and Communications, ISCC'04, vol 1(2004), pp. 244–251.

[29] M Buettner, GV Yee, E Anderson, R Han, X-MAC: a short preamble MAC protocol for duty-cycled wireless sensor networks, in Proceedings of the 4th International Conference on Embedded Networked Sensor Systems, ser. SenSys '06 (2006), New York, NY, USA, ACM, pp. 307–320.

[30] P Le-Huy, S Roy, Low-power 2.4 GHz wake-up radio for wireless sensor networks, in IEEE International Conference on Wireless and Mobile Computing Networking and Communications, Avignon, France, (2008), pp. 13–18 (October 2008). doi:10.1109/WiMob.2008.54.

[31] J Ansari, D Pankin, P Mhnen, Radio-triggered wake-ups with addressing capabilities for extremely low power sensor network applications. Int J Wirel Inf Netw. 16 (2009), pp. 118–130.

Online Resources

1. www.wikipedia.org
2. www.google.com – Search Engine for data and images

Dissemination

Bishnu Prasad Sahoo, and Susmita Das **"Peer to Peer Topology Based Energy Harvesting Protocol for WBAN",** *IEEE Gloabal Conference on Communication Technologies (GCCT'15)*, Kanyakumari 23^{rd} -24^{th} April 2015.