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# Scheduled Access Strategy for Improving Sensor Node Battery Life Time and Delay Analysis of Wireless Body Area Network

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**ABSTRACT** In WBAN, energy efficiency is a major concern. The sensor nodes attached to the human body are battery-powered devices with a finite lifespan. These sensor nodes assist in gathering biological data from the human body and transmitting it to a control device. In WBAN, the MAC protocol is critical in evaluating a protocol's energy efficiency. Traditional MAC protocols aim to boost throughput and bandwidth efficiency. The most critical aspect is that they lack in energy conserving mechanism. By employing correct control techniques that aid in the efficient use of energy resources, the useful network life time can be extended. Several MAC protocols for WBAN have been devised to reduce energy consumption, and packet collision, idle listening, overhearing, and control packet overhead are the main causes of energy waste in wireless networks. Idle listening, packet overhead, overhearing, and collision rate are all addressed by the energy-saving technique. In WBAN, we introduced a novel energy-efficient MAC protocol called Scheduled Access MAC (SAMAC) to extend the network life time without sacrificing QoS. Using the Castalia simulator, we analyze and compare the performance of our proposed SAMAC to that of the BaselineMAC (IEEE 802.15.6) and ZigBeeMAC (IEEE 802.15.4) in terms of energy consumption, packet delivery ratio, and end-to-end delay. In terms of both energy conversion and WBAN Quality of Service, our simulation results suggest that our proposed SAMAC is more efficient than Baseline MAC and ZigBeeMAC.

**INDEX TERMS** Wireless body area network (WBAN), medium access control (MAC) layer, IEEE 802.15.6, scheduled access medium access control (SAMAC), energy efficiency, quality of service (QoS).

## I. INTRODUCTION

With the rapid development in the wireless technology, the Wireless Body Area Network (WBAN) has a great impact in health care patient monitoring applications [1]. The WBAN comprised of medical sensor nodes which operates autonomously and these sensor nodes measures the physiological parameters of the human body like heartbeat, temperature, glucose level, blood pressure etc. The basic components of WBAN are personnel device, Actuator and sensor nodes. The personnel device acts as a gateway for the sensor nodes which collects the information from the sensor nodes and transmit that information to the doctor's database via access point. Based on the information gathered from the human

body the doctor will take a corrective action to the patient. The applications of WBAN are huge in many fields.

The WBAN [2] supports low-cost and spontaneous health monitoring with real-time updates of medical records for patients, fire fighters, military personnel through the Internet with the help of sensors. Health monitoring signals can be detected from patients and sent to receivers via wireless mode and then communicated to the remote locations so that they can be analyzed and required measures can be taken at right time. It covers three major areas for a complete transfer of signal. The communication architecture in the WBAN is divided into three tier as mentioned in figure 1.

### A. TIER-1: INTRA-WBAN COMMUNICATION

In this level, the interaction of the sensors is confined around the body of the patient. The communication signals within

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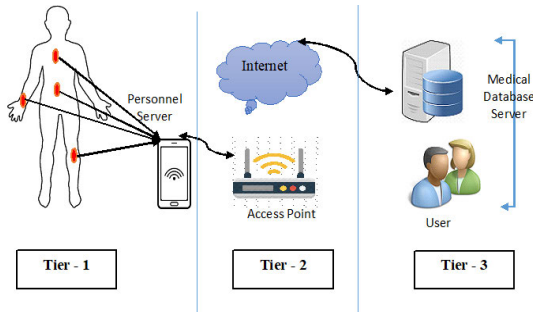


FIGURE 1. Three tier WBAN architecture.

the region use a Personnel Server (PS) that acts as a gateway, to transfer the information to the next level.

### B. TIER-2: INTER-WBAN COMMUNICATION

This level bridges the gap between the PS and the user via Access Points (APs) that are considered an important part of the network and may be positioned in a way that can allow for emergencies cases. Essentially, communication at this level strives to connect WBAN with other systems or networks so that information can be easily retrieved through mediums such as the internet.

### C. TIER-3: BEYOND-WBAN COMMUNICATION

This level of communication is ideal for metropolitan areas, as “gateway.” For example, a Smartphone can become a bridge from Tier 2 and Tier 3. From the Internet to the Medical History Database Server (MHDS) in a specific application is another good example of this type of communication. A medical environment database is a crucial part of Tier 3 communication, since it accommodates the medical history and specific profile of the user. This means that the design would necessarily need to be specific to an application; medical providers and/or patients can be alerted to an emergency situation via the Internet or through a Short Message Service (SMS). Tier-3 also allows for the restoration of important patient information that can be crucial to plan for appropriate treatment. The PS in Tier-1 could also use GPRS/3G/4G that will directly connect it to tier 3 network, without the need of an AP (Access Point), depending upon the application.

### D. SENSOR NODE DESIGN

The raw signals from the human body is collected by using the sensor nodes. These sensor nodes will perform three tasks such as detecting a signal via front end, digitizing/ coding/ controlling for a multi access communication and finally wireless transmission through radio transceiver technology as shown in figure 2. Generally micro controller will take care of data acquisition and processing but here it also maintains the power management scheme to control distribution of energy from the battery in an optimized manner. During sleep mode the battery is turn OFF and in the case of active mode it is turned ON. Here the amplifier is used to strengthen the signal which is collected from the human body and then

passes through the filter to remove an unwanted signal and noise. The next step is it will send to the Analog to Digital Converter (ADC) for digital processing. The function of the microcontroller is stores the processed signal and pack all those data for transmission via the transceiver.

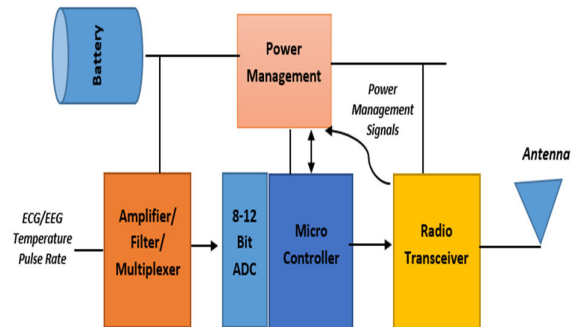


FIGURE 2. Block diagram of wireless sensor node in a WBAN.

The research work identifies the features of IEEE 802.15.6 (Baseline MAC) that do not work well for the specific characteristics of WBAN and evolved a new MAC protocol which will improve the network lifetime and reduce the packet delay latency to suit the needs of real-time nature of the WBAN.

It is planned to implement a new energy efficient MAC protocol under IEEE 802.15.6 slotted CSMA/CA with beacon enabled mode on the basis of a novel idea which combines two optimizations methods i.e., MAC layer parameter tuning optimization and duty cycle optimization. The new protocol SAMAC (Scheduled Access Medium Access Control) can be able to improve the energy efficiency and the quality of service in Wireless Body Area Network. Further we intend to analyze the proposed MAC protocol using Castalia simulator and evaluate its performance.

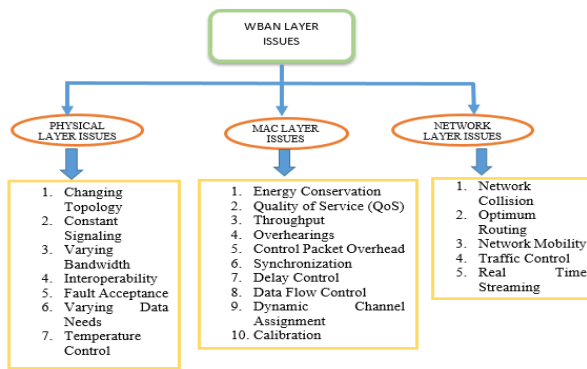
## II. RELATED WORKS

The internal design of WBAN has a layered architecture. Each layer facing different issues in designing and implementing the WBAN in real time applications which has been shown in the figure 3 [3]. In this paper we concentrate on Medium Access Control layer (MAC) issues mainly deals with energy conservation and Quality of Service (QoS). The following are some of the issues in the MAC layer.

The research work deals with the study of the existing MAC protocols for WBAN and propose a new MAC protocol based on the existing Baseline MAC (IEEE 802.15.6) which can address the following issues like energy efficiency, packet delivery latency, end to end delay. The existing Baseline MAC mainly concentrated on the less energy conservation. Thus to improve both energy efficiency and Quality Of Service, we propose a new MAC protocol and the result is compared with Baseline MAC and ZigBee MAC protocol.

### A. ENERGY CONSERVATION

The main sources of energy consumption [16] in a WBAN are Control packets overhead, retransmission, over-emitting,



**FIGURE 3.** Classification of WBAN layer issues.

collision, idle listening, traffic fluctuation and overhearing. So, there is a need to make optimum use of energy.

### B. QUALITY OF SERVICE

QoS issues measure communication throughput, reliability and energy efficiency can be achieved by adaptive channel coding, power scaling and time slot division.

### C. THROUGHPUT

The reason for low throughput in a WBAN is the exchange of control packets and low duty cycles. Hence for better performance there is requirement of a self-adjustable duty cycle.

### D. OVERHEARING

Overhearing occurs when a node receives a packet that is not destined for it but is destined for some other nodes. Accepting irrelevant packets leads to waste of energy.

### E. CONTROL PACKETS OVERHEAD

Control packets reduce the network's throughput as they do not convey any data and also they consume lot of energy. So there should be ways to keep control packets as low as possible during communication.

### F. SYNCHRONIZATION

Synchronization [16] represents the continuous acceptance of communication packets under energy and throughput formation. For real time data delivery Synchronization has to be improved.

### G. DELAY CONTROL

Low duty cycles lead to High delay [16] of packets. Instead of saving data on the local memory of the sensor nodes it should be forwarded instantly. Doing this can reduce Transmission Delays to a larger extent.

### H. DATA FLOW CONTROL

Flooding at receiver side causes propagation delay and transmission delay. Decrease in such delays can be done by keeping control on the flow of data rates.

### I. DYNAMIC CHANNEL ASSIGNMENT

Intelligent bandwidth assignment or dynamic channel sharing must be provided to avoid low throughput, high delay, high loss which occurs due to noisy channel or interference.

### J. CALIBRATION

Calibration of a WBAN system isn't an easy task. It consumes a lot of time due to several factors such as random noise, failure of sensor nodes, changing environment having several environmental issues such as blockage of node, delay, damage, random errors, aging etc.

As part of the literature review, a few selected recent and relevant works have been studied and the methodologies, pros and cons are summarized in the following

According to Sruthi [4], resource efficiency is a big issue when it comes to developing the various MAC protocols for WBAN [4]. Many MAC protocols, such as Body MAC, IEEE 802.15.4, IEEE 802.15.6, Battery Aware TDMA Protocol, Energy Efficient Low Duty Cycle, and others, were created with low power consumption in mind. The hybrid protocol, according to the author, is the most effective way to attain great energy efficiency.

In WBAN, Farhan Masud *et al.* [5] reviewed traffic adaptive Medium Access Control (MAC) protocols. They classified the MAC protocols according to their metrics, methodology, and evaluation aims. In terms of traffic adaptive techniques, the ZigBee standard and Baseline MAC were examined and their performance compared in terms of latency, Packet Delivery Ratio, and energy usage [5].

The lifetime of devices and latency are two important issues in WBAN applications, both of which fail to meet WBAN standards [6]. Anil K Jacob *et al.* [6] developed a MAC protocol based on the IEEE 802.15.6 CSMA/CA mechanism, as well as a sleep mechanism for the devices, in order to extend the network lifetime of the devices and to account for latency in a typical WBAN network in a hospital setting.

There are two modes of operation for WBAN nodes: all transmit and few transmit. According to Chong-Qing Zhang *et al.* [7], using a few transmit modes rather than all transmit modes is an effective technique to prolong the battery life of the sensors node. The author created an adaptive MAC protocol to serve nodes that only transmit a few times per second. The FT-MAC protocol is efficient both in terms of power consumption and in terms of performance.

Jaeho Lee and Seungku Kim [8] has been stated that energy efficiency is a major problem in WBAN. The MAC layer plays the major role in solving this issue efficiently. The author proposed a new energy efficient MAC protocol which is based on the asymmetrically energy-balanced model between nodes and coordinator. The proposed scheme loads the unavoidable energy consumption into the coordinator instead of the nodes to extend their lifetime [8].

For energy efficiency, Jingjing Yuan *et al.* (2013) [9] suggested the Enhanced MAC (EMAC) protocol. The protocol

selects a reliant node for a node that may be experiencing an energy shortage in order to extend its longevity, according to the inventor. When sensor nodes have data packets to transmit, however, a dynamic power control method is used to save even more energy.

Yang *et al.* (2018) [10] created a new medium access control (MAC) layer protocol to improve the energy efficiency and lifespan of body sensor nodes in WBANs. The proposed protocol combines carrier-sense multiple accesses with collision avoidance and time division multiple access algorithms to create a hybrid approach. In addition, to improve energy efficiency, the authors allocate the major transmission overhead at the personal station side and create a new awaiting order state for sensor nodes.

Kong (2020) [11] authors objective is to maximize the sum of cellular throughput while avoiding collisions among co-located WBANs and satisfying QoS requirements of health-care applications. Evaluation results confirm that WBAN collisions can be avoided at a crowded pedestrian walkway, even when there are as many as 6 pedestrian arrivals per second.

Michaelides *et al.* (2019) [12] introduced a novel programmable MAC strategy that only requires a modest adjustment to the IEEE 802.15.6-2012 beacon frame. The key contribution of the authors is the addition of a command to the beacon, which is broadcast by the hub at the start of each super frame.

The proposed effort by Jafer *et al.* (2020) [13] is to outline the design process of a wireless body area network (WBAN) for remote monitoring of numerous physiological signals from a patient. The authors included different sensors into the WBAN, including temperature, heart rate monitor using electrocardiography, and accelerometer to detect fall and seizure conditions. Data from the sensors has been wirelessly transferred to a central control unit (CCU) connected to a remote base station. Using a CCU-based gateway with GSM modem capability, sensor data can be moved to the cloud. This method makes it possible to access sensor data from a distance. The Zigbee mesh topology was used to wirelessly connect Radio Frequency (RF) equipment.

Shen *et al.* (2019) [14] proposed a marginal utility theoretic method to allocate the radio resource to the on-/in-body sensors in a fair and efficient manner. Especially, they consider that the sensors are wireless powered by multiple pre-installed radio-frequency energy sources. First, the utility function for a sensor node is proposed, which can map the achievable throughput to a satisfaction level of network QoS. Then, the authors proposed the fairness resource allocation among the sensor nodes is modeled as a sum-utility maximization problem.

Bilandi *et al.* [15] aims to compare the performance of the three most recent nature-inspired meta heuristic algorithms for solving the relay node selection problem. The authors found that the total energy consumption calculated using grey wolf optimization decreased by 23% as compared to particle swarm optimization and 16% compared to ant lion

optimization. They suggested that grey wolf optimization is better than the other two techniques due to its social hierarchy and hunting behavior. The findings showed that, compared to well-known heuristics such as particle swarm optimization and ant lion optimization, grey wolf optimization was able to deliver extremely competitive results.

Boumaiz, M., *et al.*, [16] provide a comprehensive overview of energy harvesting systems as well as ways in the literature for maximizing the use of captured energy in a WBAN using Mac, routing, or physical layer protocols.

Pruthviraj Rajaram Ghatge, *et al.*, [17] focused on strategies that were utilised to extend the network lifetime by reducing the energy consumption of sensor nodes that were placed on the patients' bodies or in their cells. The SMAC and WISEMAC protocols are used in WBAN to cut down on energy consumption.

Nathan Geddes, *et al.*, [18] suggested a data classification and aggregation procedure that improves energy efficiency by lowering the amount of energy necessary to send each data measurement. Because aggregation is performed at the sensor or node level, it is suited for a variety of sensors running at varying sampling rates and varied WBAN configurations as compared to the previous protocol.

The authors also offer their experience with the proposed protocol on prototype wireless sensor nodes that they have constructed. The protocol has proven the ability to provide considerable increases in energy efficiency through an energy efficiency analysis based on the IEEE 802.15.6 body area network standard.

Damilola D. Olatinwo, *et.al* [19], investigates some key MAC protocols that could be exploited in WBANs based on their characteristics, service specifications, technical issues such as energy wastage issues, and possible technical solutions were provided to enhance energy efficiency, channel utilization, data transmission rate, and dealy rate. Also, these MAC protocols were grouped and compared based on short- and long-range communication standards. Following this, future directions and open research issues are pointed out.

### III. ARCHITECTURE OF PROPOSED SYSTEM

The IEEE 802.15.4 MAC protocol is the industry standard for low-rate wireless personal area networks and is frequently utilized in wireless body area network testbeds and simulation. However, this standard is only adequate to a certain extent. Various MAC protocols for WBAN have been proposed by a number of researchers. The WBAN has unique characteristics that necessitate careful MAC protocol tuning in order to achieve the dual goals of increased network lifetime and reduced packet delivery latency. We want to create a new energy-efficient MAC protocol called Scheduled Access MAC (SAMAC) for Wireless Body Area Networks based on the IEEE 802.15.6 standard. This protocol will solve wireless body area sensor network quality of service (QoS) criteria, such as lower packet latency and lower energy usage.

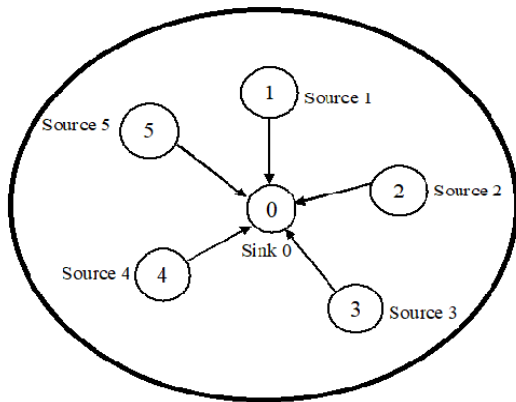


FIGURE 4. One hop star topology.

A. SAMAC ACCESS MECHANISMS

The SAMAC supports the following access mechanisms.

1) CONTENTION ACCESS METHOD

Based on the PHY layer, the hub will choose the slotted CSMA protocol. Once the beacon starts, the specific slots are given to the nodes at the start of the frame itself.

2) SCHEDULED ACCESS METHOD

In this method, the node can access the certain slots at every frame freely by sending the demand messages to the hub. When the node gets permission from the hub, the wakeup periods is considering as the super frame periods.

3) POLLING ACCESS METHOD

This method is used when there is no need of before reservation of slots in super frame boundaries. When needed, the hub selects specific slots to be assigned to appropriate nodes from the current frame only. It then transfers poll commands indicating the number of slots of prompt polled access.

This approach is to propose a SAMAC protocol under the IEEE 802.15.6 slotted CSMA/CA(carrier Sense Multiple Access) with beacon enabled mode with super frame boundaries. The optimizations method used here is that, tuning the MAC layer parameters by adjusting the scheduled access period for packet transmission.

Four elements influence the proposed SAMAC: offered network traffic load, scheduled access slot, random access slot, and allocation slot. For patient monitoring applications, the suggested protocol simultaneously delivers the required set of QoS (delay, packet delivery ratio, and efficient energy use). By adjusting the number of nodes and offered network traffic, the suggested protocol’s performance is calculated based on average end-to-end delay, packet delivery ratio rate, and energy usage. In comparison to other current protocols, the suggested MAC performed well in terms of latency, packet delivery ratio, and energy usage under the restrictions of patient monitoring applications. Figure 4 depicts the star topology employed in our situation.

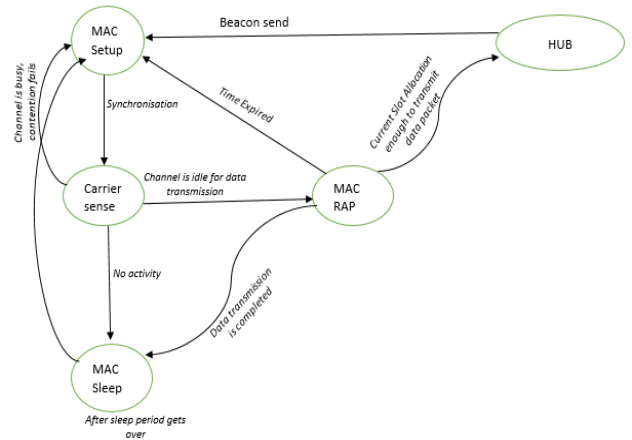


FIGURE 5. State transition diagram for baseline MAC.

B. STATE TRANSITION DIAGRAM FOR SAMAC AND BASELINE MAC

The state transition diagram for Baseline MAC and SAMAC is shown in figure 5 and 6. In this hub will send the beacon to the source node for synchronization process. The node will sense for the wireless channel for connection establishment, if the connection gets success the node is moved from MAC Setup to MAC RAP (Random Access Phase). Now the node again checks whether there is sufficient allocation slot length is available for data packet transmission or not. If there are no enough slots to transmit the data it will move again to MAC Setup, else the node can transmit its packet completely and the node moved from MAC RAP to MAC sleep till its sleeping period get expired.

In the case of our proposed SAMAC, once the connection gets established the node check for sufficient allocation slots. If the time period is not sufficient, the node will switch over from MAC Setup to MAC Free\_Tx\_Access and sends the request to the hub. The hub will send the acknowledge message to the source node for free transmission at every frame.

The proposed SAMAC protocol working mechanism is shown in the algorithm. The list of notations used in the SAMAC algorithm is listed in the table 1.

IV. ALGORITHM FOR PROPOSED SYSTEM

Figure 7 represents the algorithm for SAMAC protocol. The node performs the Clear Channel Assessment (CCA) before transmission and randomly initializes the value for back counter randomly. If CCA is busy then Connection establishment fails; lock the BC value. Initially the BC value is assigned randomly i.e. from(1, CW<sub>min</sub>). If the is found to be clear the is ready for transmission and the connection establishment is successful, and then the channel checks whether the current time is sufficient for the frame transition, if so the Back Counter value is reduced by 1 and Node can transmit the packet to the sink during RAP slots and wait for ACK. Once the ACK is received the MAC state is go to

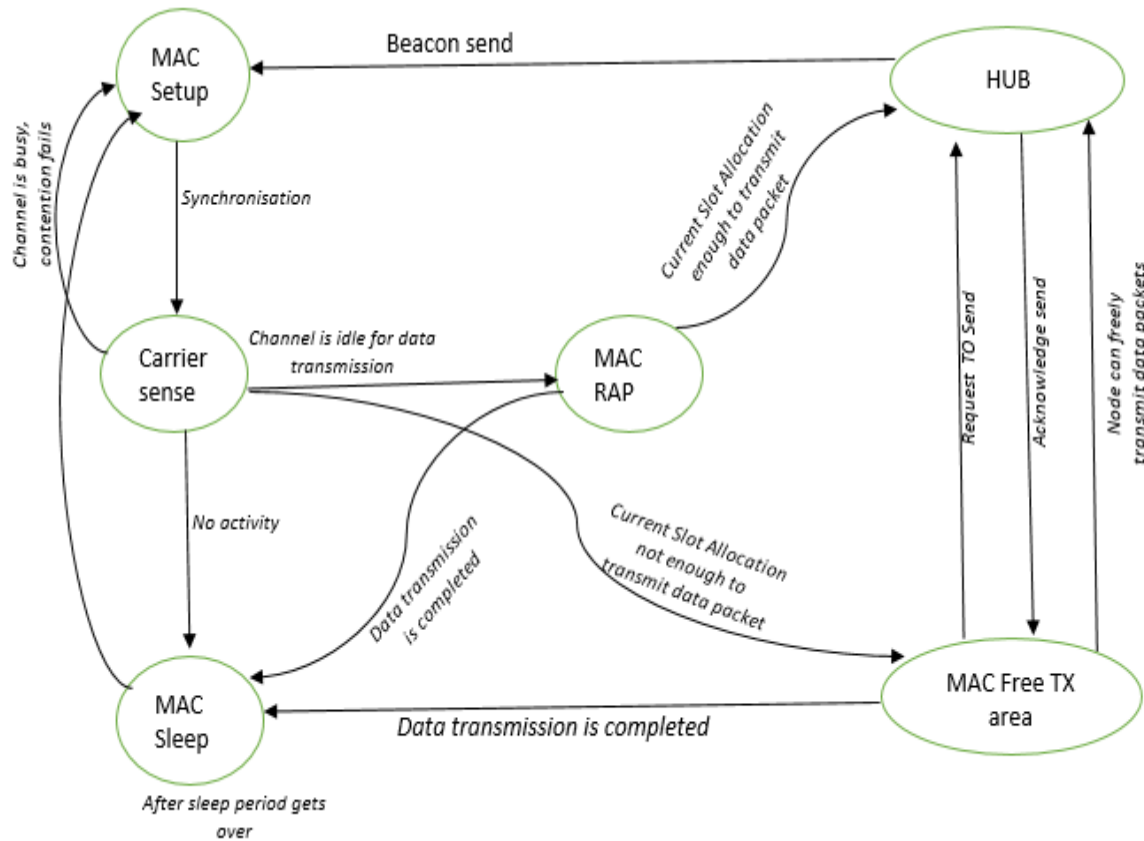


FIGURE 6. State transition diagram for SAMAC.

sleep mode, if not the channel checks the Scheduled Access Length (SAL) is greater than zero. Now the MAC state is assigned for scheduled free time access and the Node can transmit its packet freely during schedule access period and wait for ACK. If the node is unable to transmit the packet successfully then the transmission counter value is increased by 1 i.e.  $(K = K + 1)$ . If the K value is even we twice the CW value and checks for  $CW > CW_{max}$ . If the ACK is received it implicates the node is successfully gets transmitted.

V. IMPLEMENTATION OF PROPOSED SYSTEM

The simulation environment is Castalia 3.2, [20] and simulation platform is Windows 10. The topology used here is star topology. This is single hop star network with five sources and one sink node. Packets from all the source nodes (1, 2, 3, 4 and 5) flow towards sink node 0.

In simulation experiments, we considered two different scenarios to evaluate performance of our proposed SAMAC protocol. The first scenario is retaining number of nodes constant (six nodes) and vary rate of packets. In second scenario, we are keeping rate of packets as constant (5Kbps) and vary number of source nodes. Since it is one hop star network, we increase the node size by twice that is from 6, 8, 10, 12 source nodes which is suitable for the real time application. We calculated average consumed energy (mJ),

TABLE 1. List of notations used in the SAMAC algorithm.

Sl. No.	Notations	Explanation
1	CW	Contention Window (User Priority value)
2	K	Transmission counter failure (times)
3	RAP	Random Access Phase (slots)
4	SAL	Scheduled Access Length (slots)
5	BC	Backoff Counter (random integer value)
6	CCA	Clear Channel Assessment
7	Tx	Transmission
8	ACK	Acknowledgement

Packet Delivery Ratio (PDR) in percentage and end to end delay (ms) for proposed SAMAC, ZigBeeMAC and Baseline MAC respectively.

Thus, the performance evaluation of each MAC protocol is analysed and the implications are explained in each figures separately. However our proposed SAMAC protocol performance is better in terms of energy efficiency [21] and the QoS for the WBAN. Because of the Scheduled Access methodology the nodes get free time access for the transmission

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Input:  $CW_{min}$ ,  $CW_{max}$ ,  $K=0$ , RAP slots, SAL slots
Initialisation:  $BC = \text{random}[1, CW_{min}]$ 
 $K++$ 
Node performs CCA before transmission
IF CCA = BUSY THEN
    Connection establishment fails; lock the BC value and go to step 3
ELSEIF CCA = Clear THEN
    // Connection establishment is successful //
    IF The current time is sufficient for frame transmission, THEN
         $BC = BC - 1$ 
        IF  $BC = 0$  THEN
            MAC state  $\leftarrow$  MAC RAP
            Node can transmit the packet to the sink during RAP slots and wait for ACK
            MAC state  $\leftarrow$  MAC Sleep
        ELSE
            go to step 3
        END IF
    ELSE IF schedule access length  $> 0$  THEN
        MAC state  $\leftarrow$  MAC Schedule Free_Tx Access
        Node can transmit its packet freely during schedule access period and wait for ACK
        MAC state  $\leftarrow$  MAC Sleep
        IF ACK received or  $K > \text{max tries}$  THEN
            Node successfully transmits the packet
        ELSE
             $K = K + 1$ 
            IF  $K$  is even THEN
                 $CW = 2 * CW$ 
                IF  $CW > CW_{max}$  THEN
                     $CW = CW_{max}$ 
                    Go to step 3
                ELSE
                    Go to step 3
                END IF
            ELSE
                Go to step 3
            END IF
        END IF
    END IF
    Go to step 1
END IF
END IF
STOP

```

**FIGURE 7.** Algorithm for SMAC protocol.

and it reduces the End to End Delay ratio as compared to the existing MAC protocols which is the most important characteristics of WBAN.

#### A. PARAMETER CONFIGURATION

Table 2 consists parameters for proposed SAMAC protocols. The following parameters are important for all set of experiments, which is required to perform in Castalia Simulation Tool. This efficiency in energy consumption of our SAMAC is achieved by adopting scheduled access mechanism which helps the source node to reduce the packet retransmission and idle listening problem in the network. This will prolong the network life time of the WBAN.

#### B. PARAMETER CONFIGURATION

Table 2 consists parameters for proposed SAMAC protocols. The following parameters are important for all set of experiments, which is required to perform in Castalia Simulation Tool. This efficiency in energy consumption of our SAMAC is achieved by adopting scheduled access mechanism which

helps the source node to reduce the packet retransmission and idle listening problem in the network. This will prolong the network life time of the WBAN.

#### C. ANALYSIS OF EXPERIMENTAL RESULTS

The length of packet is fixed to 1000 Bytes during entire simulation experiments. We measured three metrics (consumed energy, PDR and delay) in two different cases.

##### 1) CONSUMED ENERGY ANALYSIS

Figure 8 depicts the average energy consumption as a function of the number of nodes. When compared to the Baseline MAC and ZigBee MAC, our simulation findings suggest that the proposed SAMAC consumes less energy. Our suggested SAMAC uses less energy, which means that the life of a sensor network for biological applications would be extended. When compared with the Baseline MAC, our proposed SAMAC consumes 74.6% lesser amount of energy consumption. When we increasing the packet rate from 5 to 25 Kbps, it is observed that a significant improvement of consumed

TABLE 2. Simulation environment.

Parameters	Values
Simulation Time	100 seconds (1 sec for synchronisation)
Number of Nodes	6, 8, 10, 12
Sensor Node Application Name	Throughput Test
Node Initial Energy	18720J
TX Output Power	-15dbm
Application Packet Rate	5 Kbps
BeaconPeriodLength	32 slots
Allocation Slot Length	10 slots
Scheduled Access length	2 slots
Scheduled Access Period	3 times
RAP Length	6 Slots
Contention Slot length	0.36 (ms)
MAC buffer size	48 packets
Max packet Retries	2
Polling Mechanism	Enabled
macPacketOverhead	7 Bytes
pTimeSleepToTX	0.2ms
phyLayerOverhead	6 Bytes

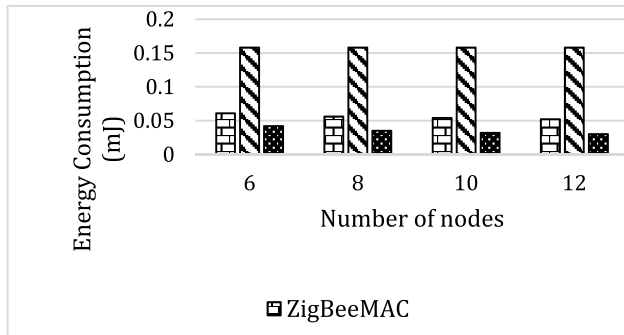


FIGURE 8. Average energy consumption (node - dynamic, traffic - constant).

energy of proposed SAMAC is decreased 0.158 to 0.043mJ when compared to that of Baseline MAC protocols which is shown in the figure 9.

2) ANALYSIS OF PACKET DELIVERY RATIO

The PDR shows how many packets were successfully delivered to the sink node from various source nodes. Figures 10 and 11 show that when compared to the Baseline MAC and ZigBee MAC, the proposed SAMAC has a greater PDR. Figure 10 shows that when the number of nodes increases, the Packet Delivery Ratio improves from 81.6 percent to 97.2 percent in the case of our proposed SAMAC protocol. In the second scenario, where the node size is kept constant and the packet rate is varied from 5 to 25 (Kb/s), we can see a significant improvement in the Packet Delivery Ratio for the proposed SAMAC protocol, which is close

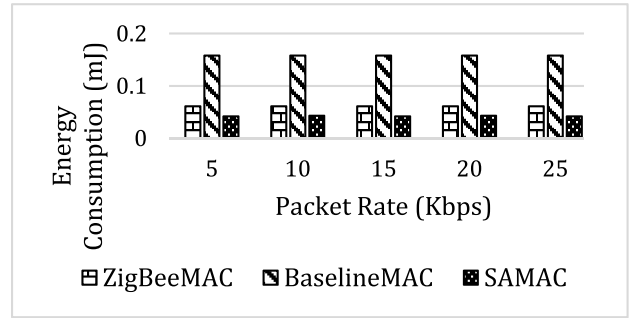


FIGURE 9. Average energy consumption (node - static, traffic - dynamic).

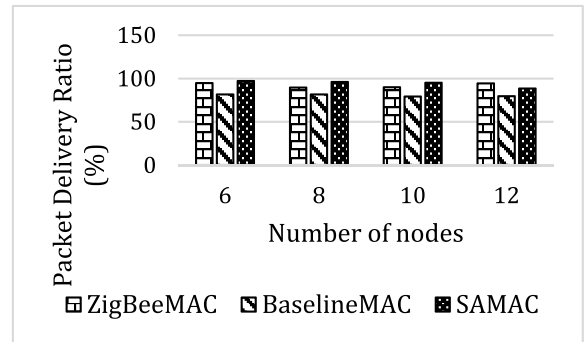


FIGURE 10. Packet delivery rate (constant traffic load, node - dynamic).

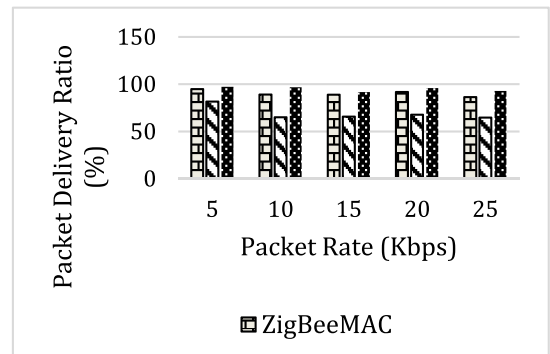


FIGURE 11. Packet delivery rate (dynamic traffic load, node - static).

to 95 percent, whereas the Baseline MAC protocol is only 65 percent, as shown in Figure 11. Since our SAMAC protocol is able to transmit its packet during in free transmission access received by hub when the contention active period is expired.

3) ANALYSIS OF END-TO-END DELAY

Figures 12 and 13 demonstrate the end-to-end delay comparison between the proposed SAMAC with the baseline MAC. In all instances, the delay in the Proposed MAC is quite short when compared to the Baseline MAC. When the nodes are dynamic, the performance of our suggested SAMAC's latency is somewhat reduced from 25% to 21%, according to simulation data. In the case of the second scenario, which involves adjusting the packet rate, the delay steadily decreases from 10% to 2% for our suggested MAC, as illustrated in Figures 12 and 13.



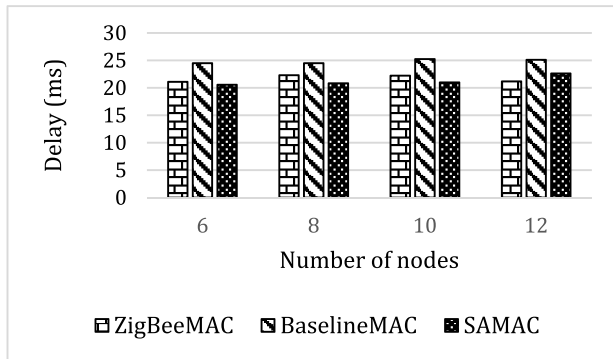


FIGURE 12. End to end delay (constant traffic load, node - dynamic).

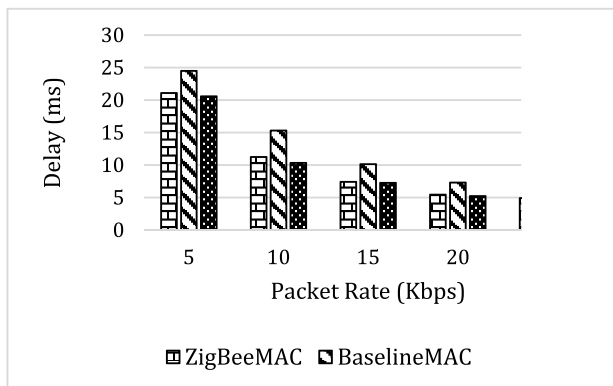


FIGURE 13. End to end delay (dynamic traffic load, nodes - static).

## VI. CONCLUSION AND FUTURE WORKS

Saving energy in media access communication is a hot topic of research. We presented an overview of WBAN, the MAC protocol for WBAN [22], and the performance of IEEE 802.15.6 on the MAC Layer in this project. Many researchers have recently proposed various MAC protocols for WBAN to monitor the human body, but there are still some concerns that need to be addressed in order to obtain a comprehensive set of QoS. To address these issues, we introduced Schedule Access MAC, a new energy-efficient MAC protocol. By tweaking the MAC layer parameters, the proposed SAMAC protocol is based on an energy efficient scheduled approach. Then, using OMNET++ and the Castalia emulator, we evaluated their performance in terms of packet delivery ratio, end-to-end delay, and average energy usage.

The simulation is conducted in two scenarios. The first scenario is by keeping the constant traffic and varying the number of nodes. The second scenario is by keeping the constant number of nodes and varying the traffic load. Based on the simulation results we synthesize that our proposed SAMAC protocol is performing efficient than Baseline MAC protocol and ZigBee MAC protocol in terms of energy consumption as well as great improvement in the quality of services as required by WBAN.

As future work, we intend to implement more enhancements at the MAC layer and to study the coexistence of WBAN and interferences issue, and how we can mitigate their impacts. Since data privacy and data management is another challenge of the WBAN. Our future work can be

extended by analyzing those challenging issues in health care applications [23] and provide a solution for those problem.

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