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Implementation of Efficient Mac Protocols for wireless Senosrs in WBA Networks

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***Abstract:** Various medical applications consisting of heterogeneous requirements are supported by WBA networks. For reliable data transmission it is required to use an efficient medium access control protocol. Here, in this project, a dynamic Super frame structure-based MAC protocol is proposed by extending the standard principles from IEEE 802.15.6 which is a standard protocol, a mechanism for allocating dedicated slots with prioritization is used which is known to be Criteria Importance Through Inter-criteria Correlation, inorderto assign the allocation of slots for every sensor device. Values of sensor devices are calculated based on different sensors parameters by using CRITIC method. There by we compare our proposed work with the standard IEEE 802.15.6 MAC and other MAC protocols. By simulating it is shown that our proposed MAC protocol has performed better in Reliability, Throughput, Energy Efficiency and also Packet Delivery Delay. In the results it is shown that Reliability of data transmission has increased over more than 50% over the standard IEEE 802.15.6 MAC.*
***Keywords:** Wireless Body Area Networks (WBAN), Criteria Importance Through Inter-Criteria Correlation (CRITIC).*

I. INTRODUCTION

The future of healthcare is MOBILE healthcare via Wireless body area networks (WBAN).WBAN is often made up of a variety of independent on-body physiology monitoring sensor devices that are all wirelessly linked to a central coordinator (or hub). By continuously or sporadically monitoring physiological processes including blood pressure, breathing, heart rate, ECG, body temperatureetc.,[1],[2],[3], [4]. WBANs data collection during routine health monitoring helps to speed up and improve the accuracy of the diagnosis. Recently, we have also seen a sharp rise in the use of WBANs in numerous heterogeneous applications for a variety of industries, including sports, the military, gaming, and even in conjunction with various cutting-edge enabling technologies, like software-defined networks (SDNs), big data and the Internet of Things(IoT)[5],[6],[7],[8],[9].

In a WBAN, physiological monitoring sensors vary depending on variety of factors, including user priority (UP), packet generation rate, data transmission rate,packet size, buffer capacity, etc. The total effectiveness of a WBAN is significantly influenced by all of these sensor settings.The differences between the sensor devices are not taken into account in the existing studies based on the IEEE 802.15.6 standard. In this study, all these issues were taken into account when deciding which sensor equipment to use. The main objective of the proposed project is to increase the efficiency and reliability of WBAN as a whole by allocating certain time slots for specific equipment according to a certain time (fixed boot time).

A. In Brief Description of the MAC Protocol for IEEE 802.15.6

Wireless body area networks (WBANs) have become a crucial component of many fields and are still developing thanks to research in areas like energy efficiency, data quality, and Quality of Service (QoS). Although WBANs are part of the larger family of sensor networks, they play a unique role since they assess people rather than their surroundings.This makes it clear that, similar to how no two people are the same, so too may the utility of WBANs vary widely. A user might need intensive electrocardiogram (ECG) monitoring, whilst another user would need intensive blood pressure monitoring. Furthermore, it's not always possible to predict when a piece of sensor data will become crucial.As an illustration, a patient with lung disease might have sensors that measure the most significant sensor. ECG sensor data, however, may at any moment be crucial in the event of a heart-related emergency, such as a heart attack.

The IEEE Standards Association's 802.15.6 standard for WBANs included three access modes in addition to planned and unscheduled access:

1) *Beacon Mode with Beacon Periods:* Access modes that contains bounded access periods (beacon periods) that are organized by a beacon transmitted at the beginning of each corresponding beacon period and contain phases for scheduled and unscheduled access.

2) *Non-beacon Mode with Beacon Periods:* The access time is constrained by beacon periods, with unscheduled access taking up the entire time during each period.
3) *Non-beacon Mode without Beacon Periods:* Unscheduled access makes use of all time slots and is not constrained by a beacon period.

Our attention was concentrated on the first of these three: beacon mode with beacon periods, which satisfies our desire for flexibility in our MAC protocol by allowing a combination of planned and unscheduled access. In this access mode, the hub polls the sensor nodes and then broadcasts a beacon with the current beacon period's scheduling data. Important and/or emergency data from a sensor(s) may request to use the EAP phase, in which it communicates to the hub alone and avoids interference. In the RAP phase, all additional sensor nodes with less crucial data may then compete to transmit to the hub using CSMA/CA or another collision avoidance technique.

In 2012, the IEEE working group developed IEEE 802.15.6, a standard for modeling communication between sensor devices connected to WBAN. [10]. The hub must function in one of the three access modes described in the standard. The access mode that proves most beneficial is beacon mode with beacon periods since it strives to synchronize communication among different sensor units. In this mode, the hub divides the time axis into super frames (SFs), which are equal-length beacon periods. Beacon frames, which provide data about the network and SF structure, are broadcast by the hub at the start of each SF, with the exception of the inactive SFs. As shown in Fig.1,the medium access control (MAC) SF structure of IEEE 802.15.6 is made up of a variety of access phases, including two Managed Access Phases, one CAPs, two RAPs, and two EAPs. Table I provides a summary of these Access Phases' specifics. Table II lists UP mapping with data traffic type.

According to the standard, all access phases other than RAP1 may have lengths of zero during a beacon phase. Depending on the demands of the application, the hub determines the length of each access phase.

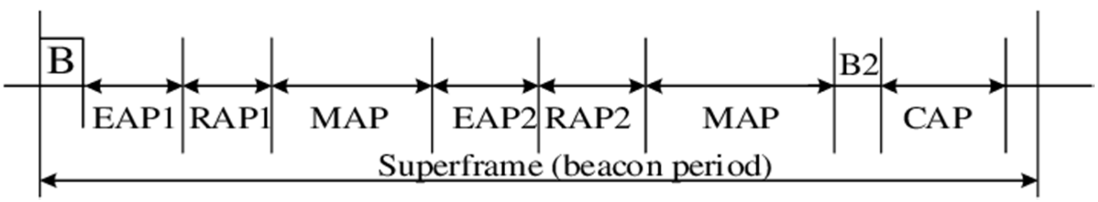

Figure 1: Superframe alignment for IEEE 802.15.6 MACs when operating in beacon mode with beacon timing.

TABLE 1
STAGES OF ACCESS AND METHODS FOR ESTABLISHING CONNECTIONS.

Access Phase	Full Name	Description	Access Method
EAP1	Exclusive Access Phase 1	Transmit data with highest UP, or emergency data, i.e. UP7.	Nodes Contend for resource allocation using either CSMA/CA or Slotted ALOHA
EAP2	Exclusive Access Phase 2		
RAP1	Random Access Phase 1	Transmits all kinds of traffic.	
RAP2	Random Access Phase 2		
CAP	Contention Access Phase		
MAP1	Managed Access Phase 1	Used for uplink, downlink, bilink, and delay bilink allocation intervals.	Type I/II polling mechanism is used.
MAP2	Managed Access Phase 2		

The EAP layer in the IEEE 802.15.6 standard is long and is used only for fast data transmission.

If there is no emergency data present in the network at a given time, the entire EAP phase will be forfeited due to the finite length of EAPs. Additionally, The emergency data cannot be fully transferred by the fixed-sized EAPs when there are many of them, which would deteriorate the emergency data transmission. We introduced the idea of dynamic length EAP to address this issue.

It is not ideal for channel allocation for the emergency data to contend within the EAP phases under the IEEE 802.15.6 standard. In our proposed work, Time Division Multiple Access (TDMA) was employed to assign dedicated slots for emergency data within the EAP.

TABLE 2
USER PRIORITY MAPPING [9]

User Priority	Traffic Designation	Frame Type
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
7	Emergency or medical implant event report	Data

The following are the contributions of the suggested MAC.

1) The MAC solution put forth in the proposal takes into account a hybrid SF structure with dynamic EAP and MAP.
2) The Criteria Importance Through Inter criteria Correlation (CRITIC) approach is used to prioritise sensor devices based on the values assigned to different parameters and the significance of the criteria.
3) Dynamically added special windows in the MAP assign each sensor device a specific slot based on its priority rating.
4) In contrast to the MAC protocol defined by the IEEE 802.15.6 standard and its several Standard versions, the suggested MAC enables reliable data transfer while consuming more throughput and less average energy.

II. RELATED WORKS

Innovative MAC methods are being proposed by researchers all around the world, designed around the original MAC protocol specified by the IEEE 802.15.6 standard framework. These research efforts, of course, has some advantages and disadvantages, which are concisely covered in this part. To prevent contention and ineffective use of SF time, Zia et al. [11] presented a novel group-based traffic classification in the IEEE 802.15.6 standard.

An MAC technique for cross-layered energy-aware resource allocation was put forth by Chen and Chiu [12]. Regarding the protocol of maximum ratio combining, Li et al.'s joint power allocation strategy was put forth [13]. The authors created an optimisation challenge and then found a solution in order to maximise the overall network throughput. Throughput heterogeneity was addressed by Wang et al. [14],who made an effort to reduce energy use in both battery-free and battery-assisted cases. The writers approached these issues using a variety of techniques, including gradient descent, bisection search algorithms, the Lagrange dual sub gradient method, etc. To guarantee low power consumption and minimal latency for emergency data reporting, Liang et al. [15] presented the energy-aware and energy-efficient MAC (EEEA-MAC) protocol. In order to maximise throughput for each sensor, He et al. [16] presented a joint weight optimising time slot allocation methodology (JWTA), in which the weight is determined via an analytical hierarchy approach. A modified SF structure of an IEEE 802.15.4-based MAC protocol was proposed by Rasheed et al. [17] in order to reduce delay and increase energy efficiency.

Through the integration of the power cap with modifying the uncore frequency Hao et al. [18]recommended a method to approximate the Pareto-efficient power cap configurations for achieving precise energy optimization and power cap allocations to the systems with power constraints. To create a more energy-efficient structure, Cicioglu and Alhan[19] created an IEEE 802.15.6-based event driven wireless body sensor networks (WBSNs) technique. Additionally, they created a WBSN architecture for energy gathering. To lessen the damaging effects regarding the interaction of electromagnetic signals, caused by HUB placement which is fixed with the human tissue, the authors took levels of battery, particular sensor device priority and absorption rates, into consideration in one of their other research [20].

In addition to the works stated above, we also review the research below, which are more pertinent to the work that is being proposed. As we compared performance, we also used them as benchmarks. In a system developed by Enkoji et al.[21], In MAPs, the polling technique is utilized to transmit data. A MAC protocol for medical emergency devices (MEB MAC) protocol was designed by Huq et al. [22] to balance channel access delay and power usage. To enable speedy, this protocol dynamically includes MAPs within emergency traffic for channel access, facilitating the insertion of several listening windows (LWs).

In order to transfer emergency traffic reliably and swiftly, TDMA was utilized by the authors within MAPs. The SF structure of MEB MAC does not contain the EAPs. Two IEEE 802.15.6-based MAC protocols, saturation aware for the user priorities (SAUPs) and saturation Aware for the highest UP (SAH),were proposed by Sadra and Abolhasan[23]. The SF structure of SAUP and SAH also includes a phase for allocating guaranteed time slots (GTSs), in addition to other access phases. Instead of using the CSMA/CA technique, SAH assigns assigning dedicated time slots (GTSs) for emergency data within EAP via the TDMA-based approach. To increase the SF utilization of the IEEE 802.15.6 MAC protocol, Saboor et al. [24] presented a dynamic slot allocation (DSA) technique employing nonoverlapping contention windows (CWs). To prevent inter-priority collisions, the authors of this study devised the nonoverlapping back off algorithm (NOBA). In order to reduce waste caused by fixed slot size, they also implemented a DSA scheme. An adaptive SF structure-based channel access technique was put out by Deepak and Babu [25] to increase the reliability of emergency data transfer. For IEEE 802.15.6-based WBAN, Misra et al. [26] presented by MAC which is energy-efficient scheme. In this, the authors proposed an SF structure with a first half for transmission of emergency data and a second half for routine data transmission.

Synthesis: In addition to introducing the principles of EAP with dynamic length and specifically allocated slots for emergency data within EAP utilizing in addition to TDMA, it is required to have a mechanism of sensor prioritization that determines its sequence to sensor nodes for dedicated slot allocation according to the priority or the required level of their data. Hence applying the CRITC model to determine priority value based on numerous sensor-related characteristics, sensor nodes' urgency is determined. It should be noted that none of these previous works took such techniques into account. Numerous sensor parameters, including packet production rate, data transmission rate, buffer occupancy status and packet size, are important, but they are not considered in the works that have been done so far.

For instance, sensor devices with a high rate of packet production and a full buffer need quick channel access; otherwise, packet loss from buffer overflow can occur. To prioritize the sensor devices using the CRITIC technique, we therefore take into account all of these pertinent aspects in the proposed work. We also evaluatethe effectiveness of the MAC protocol proposed against a few standards. [20]–[25].

III. SUGGESTED STUDY

The major objective regarding the suggested the aim is to allocate dedicated slots with better network performance based on sensor prioritization. Designing a dynamic SF structure and assigning a high priority to sensor devices are the key obstacles we must overcome in this regard. The following sections are used to describe the suggested solution for the benefit of the readers: The proposed MAC's super frame structure is shown in A, sensor prioritization utilizing CRITIC is shown in B, C, and D, and descriptions of the aspects used for comparison are shown in A, B, and C, respectively.

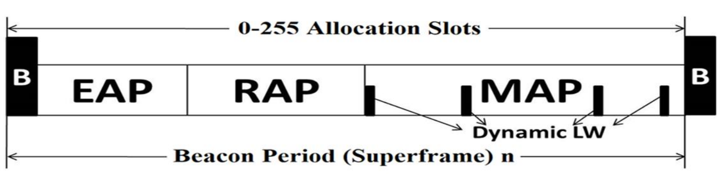

Figure 2 shows the structure of the superframe for the MAC protocol.

A. *Super frame Design of the suggested MAC scheme*

This suggested that the MAC protocol function is designed for a WBAN with a star topology, in which a hub oversees all aspects of network functioning. The period of contention-based contention and the period of contention-free operation are both present in the suggested MAC. The hub will never sleep. We take into account a flexible length MAP, a constant length RAP and a variable length EAP in the suggested MAC. We maintain the RAP's fixed length as per the IEEE 802.15.6 standard.

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The SF structure of the suggested MAC protocol is shown in Fig. 2. In EAP, we use TDMA to assign dedicated slots in descending order of priority value to all emergency sensor devices (containing UP 7 data packets). The emergency sensor devices may have quick and dependable channel access with the assignment of dedicated slots in the EAP utilizing TDMA. Within the RAP various kinds of information transmission will use the CSMA/CA technique to send their data. In order to allot spaces for various types of sensor devices, several LWs are dynamically placed into the MAP. The hub assigns slots in both the EAP and the MAP in accordance with the priority level of the sensor devices, established by CRITIC through evaluating the values of different parameters which are been received from the sensor devices.1)Variable MAP and EAP: Depending on the data the hub gathered from all of the sensors during the beacon phase a variable EAP and variable MAP can be created by varying their length. The hub determines the duration of the EAP (A_L) and the timeframe of the MAP (A_M) depending on the quantity of the information packets in emergency sensors (UP 7). The time taken to deliver all of the packets from emergency sensors that the hub captured during the beacon phase (A_T) is used to calculate the variableA_L. In math, it has the following representation:

$$A_C = \sum_{b=1}^{k_e} \frac{k_i' \times C_i}{D_i} + \left(\sum_{b=1}^{k_e} k_i' \right) \times (A_C + 2S) \qquad \text{(A)}$$

wherek_e represents the total quantity of emergency sensors,k_i represents totalquantity of packets in the i^{th} emergency sensor, and C and$D$stand for the i^{th} emergency sensor's packet size and data transmission rate, respectively. Variable$A$ stands for the amount of time needed to send an acknowledgement (ACK), and$S$ stands for the time it takes a sensor device to process a frame it has received and send back a response frame, commonly known as short interframe space (SIFS) time. There are two parts to each packet transmission: the actual packet transmission time and the acknowledgement and 2$S$for each packet.

$$A_L = min\left\{Ceil\left(\frac{A}{S_L}\right) \times (B_L - R_L)\right\} \qquad \text{(B)}$$

where time slot, SF, and RAP lengths are denoted by the letters S_L, B_L, and R_L, respectively. Here, the time length is measured in seconds (S_L), but the number of time slots is measured in A_L, R_L, A_M, andB_L. The remaining slots in the SF are used to determine how long the MAP (A_M) will be

$$A_M = B_L - (A_L + R_L) \qquad \text{(C)}$$

2) Allocating Dedicated Slots in EAP and MAP: In EAP, emergency sensors are allocated slots using a TDMA-based reserved slot distribution system. Every emergency sensing equipment will initially be sorted by the hub's prioritization value determined by CRITIC which is based on the data of the sensors. The entire number of slots available for EAP, which includes both EAP and MAP, is what is shown by the variable which is available slot. The hub then assigns all the dedicated slots for the emergency sensors so that they can transmit all of the packets in their buffer, the available slot is greater than or equal to the necessary slot. If not, emergency sensors share the available slot according to how many packets they have buffered. The variable time needed indicates the time taken to transmit $k_i$or k_i''no. of packets. k_i represents the quantity of emergency sensor packets in which the hub reserves the specific slots in the time. It is required to have available slot greater than the necessary slot, the slot which is variableis required to indicate number of time slots needed k_i'' packets for transmission. otherwise, it does not.

The placement of LWs dynamically will be the mechanism for allocating specific slots for each sensing device in the MAP come next. Similar to how slots are distributed in EAP, dedicated slots are distributed in similar way in Managed Access Phase. Thus hub then only offers required slots in EAP for emergency sensor devices as opposed to MAP. To gather data from sensor devices about various parameters, we insert several LW into MAP and assign allocated spaces in their priority value for them in the descending order. This however explains how to dynamically insert LWs into MAP. At the start of the MAP, the hub inserts a LW. If the needed slot is larger than or equal to the LWI_{min}, the following LW will be put after those slots.

The hub will wait for (LWI_{min} - required slot) slots after the sensor nodes have transmitted all of the packets in the current LW if needed slot is less than LWI_{min},. LW will keep being inserted into the MAP until there are no more slots available. The hub initializes the variable LWI_{min}, which is used to specify the minimal LW interval. The low-traffic network's sensors consume a lot of energy as a result of the frequent LW insertion.

B. *Prioritizing Sensors Utilizing CRITIC*

Various sensor characteristics are listed as input in both algorithms for allocating dedicated slots. Priority values are determined using the CRITIC approach, and sensors are arranged according to their priority values before slots are assigned. The goal, criteria, and alternatives make up the three main parts of the multi criteria weight measuring technique CRITIC [26]. The importance of sensors is still largely undetermined. Depending on the importance given, standard models represent specific indicators. Finally, and most importantly, electronic devices are included in this model and special opportunities are offered to them.

Below is a formal definition of them.

Definition 1: A sensor node's UP value represents the criticality of the data it has sensed.

The emergency information has a 7-priority value. is the highest UP data. Data traffic type UP mapping is already indicated in Table II.

Definition 2: A sensor node's buffer occupancy status (B) is determined by dividing the node's current buffer occupancy (B_{io}) by its buffer size (B_{is}). Thei^{th} sensor node's B is

$$B = \frac{B_{io}}{B_{is}} \qquad \text{(D)}$$

where B_{is}andB_{io}stand for the i^{th} sensor node's current buffer size and buffer occupancy (in kB), respectively. Due to the possibility of buffer overflow data loss, the B is a crucial consideration in the determination of priority. When prioritising sensors, highest sensor nodes B are considered as first priority.

Definition 3: The data's or message's length in a sensor node's sent frame is known as the packet size (C).

Definition 4: The data rate (D) of a sensor node is the rate of sending data. The D is referred to in this work as kilobits per second (kbps). Less time was needed for gearbox for sensors with a small C and high D. As a result, in the sensor prioritisation process, the sensor with a lower $C$and high D will be given high preference.

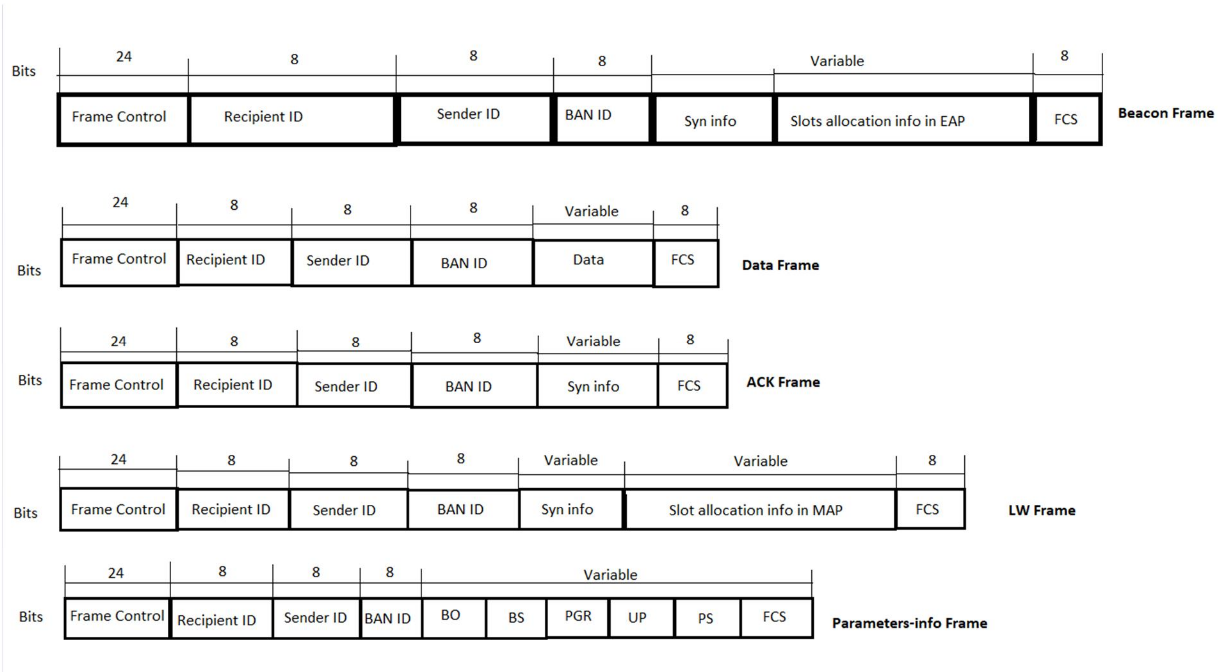

Figure.3: Frame types for the suggested MAC.

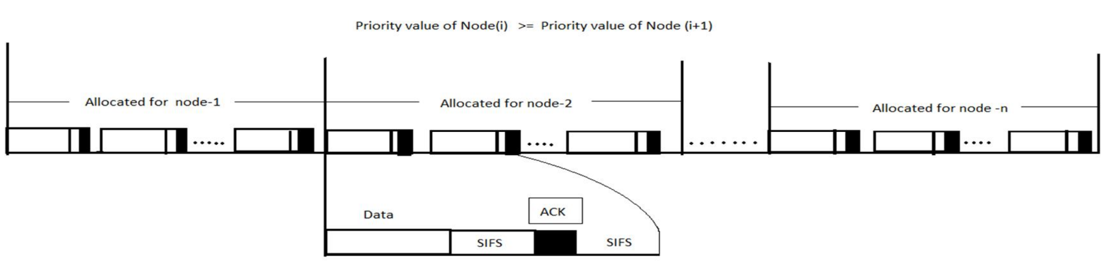

Figure:4: TDMA-based dedicated slot allocation

Definition 5: The number of packets the sensors will produce each second is known as the packet generation rate (PGR).High PGR sensors will be given top priority; otherwise, buffer overflow could result in packet loss.

The hub will analyse each sensor device separately during beacon and phase LW to record UP, B_0, B_s, CandPGRresults. As shown in Figure 3, the sensor device then sends a parameter information frame to the hub containing the parameter value. The hub then uses B_0 and $B_s$to determine B and uses received signals to determine D for the sensor device. When the sensor device does not send this information, the previous parameter is considered by the hub, which determines the priority value.

In both MAP and EAP, the framework of specialised allocation of slot for sensor devices uses TDMA technology.

After a time is allocated, the hub thus broadcasts a fixed line LW frame to each of the sensor device. The beacon frame then have the information regarding the timing and the allocation of time slots for the emergency equipment of the EAP. Information on specific time allocation for sensor devices is available in the LW framework. Figure 4, shows the operation of the core during the beacon and LW phases.

C. CRITIC Mathematical Model

CRITIC's decision-making process effectively prioritizes the objective weight of the process, which indicates how much information each measure has. This method determines the target weight based on the information provided by the two-dimensional process.

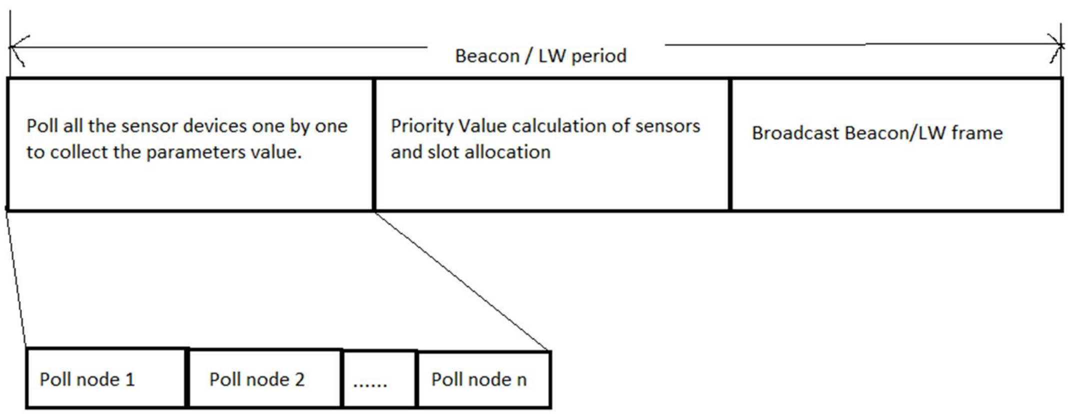

Figure.5: Hub performance during Beacon/LW phase.

The first one, which reflects each criterion separately, is the degree of contrast. The degree of contrast is measured using the standard deviation. The second is the inconsistency of the criteria as determines linear correlation coefficient. This study explains decision weights are obtained that are more realistic by combining subjective and objective weights indicated by the decision matrix with the CRITIC approach. Below is a description of the specifics of CRITIC's internal calculation, over which the hub watches.

The hub creates a $L \times K$decision matrix (D_M) with a random array of sensor devices that want to input data into the model; where$L$ is the total number of models and K is the total sensor input. Below is a representation of the $D_M$matrix

$$D_M=\begin{bmatrix} \alpha_{1,1} & \alpha_{1,2} & . & . & . & \alpha_{1,K} \\ \alpha_{2,1} & \alpha_{2,2} & . & . & . & \alpha_{2,K} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \alpha_{L,1} & \alpha_{L,2} & . & . & . & \alpha_{L,K} \end{bmatrix} \text{(E)}$$

For each p element, q represents the q^{th} parameter value of the p^{th} sensor. After receiving the parameter information frame from the individual sensor devices in the beacon phase and the LW phase, the hub gives the values of p, q and this creates the D_M matrix.

The following are the processes for determining a sensor device's priority value.

1. Decision matrix Normalization:

$$\alpha_{p,q} = \frac{\alpha_{p,q}}{\sum_{b=1}^{k} \alpha_{p,q}} \text{(F)}$$

2. Calculation of standard deviation for each criterion:

$$S_q = \sqrt{\frac{\sum_{p=1}^{K} (\alpha_{p,q} - \bar{\alpha}_q)^2}{K-1}} \text{ (G)}$$

3. Construction of symmetric matrix using generic elements:

$$C(L_q, L_r) = \frac{S(\sum L_q L_r) - (\sum L_q)(\sum L_r)}{\sqrt{\left[S\sum L_q^2 - (\sum L_q)^2\right]\left[S\sum L_r^2 - (\sum L_r)^2\right]}} \text{ (H)}$$

Where q, r= 1,2,3,….S and Criteria vectors L_q, $L_r$are as follows:
$L_q = d_1, d_2, d_3 \cdots d_s$; $L_r = d_1, d_2, d_3 \cdots d_s$;

Therefore, the symmetric matrix is expressed as

$$\begin{pmatrix} L_{1,1} & L_{1,2} & . & . & . & L_{1,S} \\ L_{2,1} & L_{2,2} & . & . & . & L_{2,S} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ L_{S,1} & L_{S,2} & . & . & . & L_{S,S} \end{pmatrix} \text{(I)}$$

Where $L_{q,r}$ =$C(q, r)$ and q, r = 1,2,3,….S;

4. Measure the conflict brought about by criterion $q$in relation to the scenario where a decision must be made as specified by the other criteria by:

$$\sum_{r=1}^{s} (1 - L_{q,r}) \text{ (J)}$$

5. Determining the Quality of Information:

$$D_q = S_q \times \sum_{r=1}^{s} (1 - L_{q,r}) \text{ (K)}$$

6. Determination of Criteria weight:

$$R_q = \frac{D_q}{\sum_{r=1}^{s} D_q} \qquad \text{(L)}$$

In the above model, the more information sent by the relevant process, the more important the calculation of the value and the higher the $D_q$value.

7. Calculation of priority values for sensor devices:

$K_p = \sum_{q=1}^{s} \alpha_{p,q} \times R_q$ (M)

Where $p = 1,2, \ldots S$.

8. Normalize the sensor values from 0 to 1 as shown in (M), where K_{min} and K_{max}represent the lowest and highest values of the sensor, respectivelyand p = 1,.. .,S.

$K_p = \frac{K_P - K_{min}}{K\,max - K_{min}}$ (N)

The proposed mathematical model considers each sensor device individually to significantly reduce cost while providing a specific time. The dual link distribution is the relay node and the relay nodes uplink to send data are the two ways in which the MAC concept can be developed for 2-hop transmission.

D. Detailed Description of Comparative Aspects

Below are definitions of the major network performance measures used in this study to assess the performance of the network.
Definition 6: The likelihood that a sensor node will successfully transport a packet is known as reliability (R) [27].
The reliability of a sensing device is described mathematically as:

$R_e = \frac{p_s}{p_g}$ (0)

where Ps is all the smart packets transmitted by the sensor and $Pg$is all the packets generated by the sensor.
Definition 7: The sensor's packet delivery delay (P_{Dd}) is the time between when the sensor generates the packet and when it is received by the hub. The types of sensor devices that send slow data to are as follows:

$$P_{Dd} = \frac{\sum_{p=1}^{S} \sum_{q=1}^{p_{s_i}} de_q}{\sum_{p=1}^{S} P_{s_i}} \quad \text{(P)}$$

where P_{s_i} is the number of packets successfully transmitted by the p^{th} sensor, S represents the number of sensor devices, and de_q is the delay of theq^{th} packet transmitted at the p^{th}sensor.
Definition 8: The energy consumption (EC) of a sensor device is the total energy used by the transceiver during transmission. The total energy consumption of the
sensor is calculated by calculating the energy consumption of the sensor in various operating modes, including generating, transmitting, receiving and sleeping[28]. In our simulations, we calculated the normal energy consumption (EC) required to process 1 KB of data. The energy used is kilobit and data is calculated as:

$$EC = \frac{\sum_{p=1}^{s} v \times \{(T_p \times T_C) + (Tr_p \times R_C) + (Tw_p \times w_C) + (Ts_p \times S_C)\}}{\Delta} \quad \text{(Q)}$$

where s, T_C, R_c, w_C, andS_c stand for the number of sensor nodes, as well as the transmission, receive,sleep and wake-up currents, respectively. The p^{th} sensor's time in transmission mode, reception mode, wake-up mode, and sleep mode are denoted by the letters T_p, Tr_p, Tw_p, and Ts_p, respectively. The unit kilobits represent the total amount of data transmitted by all sensor devices.
Definition 9: Network throughput (TP), calculated in bits per second (bps), is the average amount of data transmitted per second. By taking the average of the data transfer rate (in kbps) in all sensor devices, efficiency was determined from our experiments. Estimates are as follows:

$TP = \frac{\Delta}{N \times S_t}$ (R)

where N and S_t stand for, respectively, the number of sensor devices and simulation time. In kilobits,Δ stands for the total amount of data transmitted by all sensing devices.

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IV. PERFORMANCE EVALUATION

The suggested MAC protocol was simulated in MATLAB, and the average of 100 simulation runs was used to get the findings. The suggested MAC protocol's performance is compared to MEB MAC [21], IEEE 802.15.6 MAC [9], and other benchmark works. The star topology, in which the hub is linked to numerous sensor devices, was taken into consideration. Table III provides a summary of the simulated parameter values. Table IV displays the details of the simulation criteria that were employed. The proposed MAC's SF structure specifications are disclosed, together with those for existing benchmark MAC protocols[9], [20]–[24]. where the lengths of the EAP, RAP, MAP, CAP, and LW, respectively, are $LEAP$, $LRAP$, $LMAP$, $LCAP$, and LLW, and $LWint$ denotes the LW interval.

Table III
Parameters used for Simulation.

Parameter Name	Value	Parameter Name	Value
Super frame Length	255slots	Voltage supply	3V
Slot Length	5ms	Transmission current	12mA
MAC Header size	8 Bytes	Receive current	15mA
FCS	4 Bytes	Wake-up current	8mA
Beacon size	17Bytes	Sleep current	2mA
ACK size	Bytes	Simulation Time	60 s

Table IV
Criteria Values for Simulation

Standard Name (Criteria)	Value Range
User Priority (UP)	(0-7)
Packet Size (PS)	(40-208) Bytes
Packet Generation Rate (PGR)	(20-60) Packets/s
Data Transmission Rate (DTR)	(40-500) Kbps
Buffer size (BS)	(1-5) Kbytes

A. *Performance Comparison*

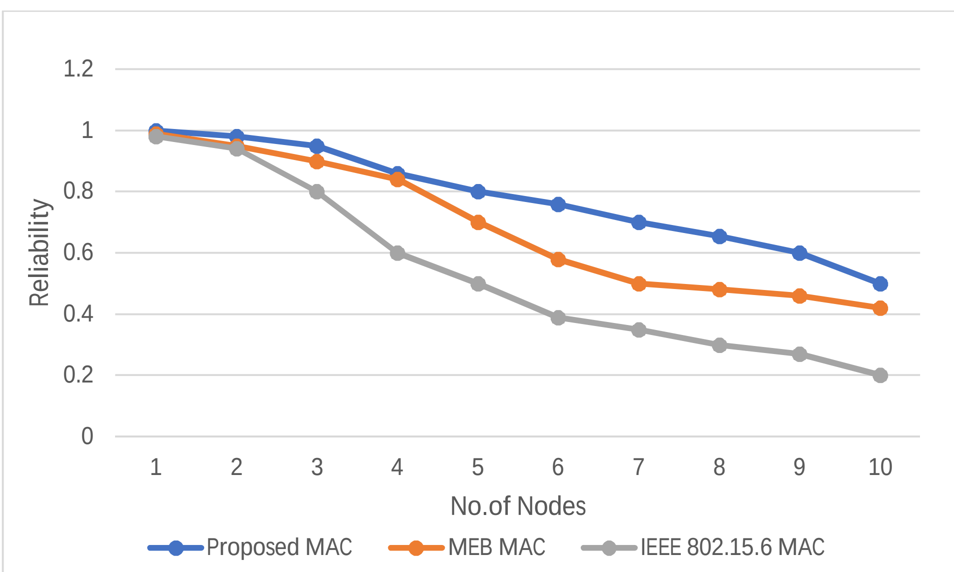

Figure.6(a):Comparing the overall reliability of data transmission.

The proposed system broadcasts the SF dynamic model and uses TDMA for priority as a certain time for each sensor device, thus improving the reliability of data transmission.

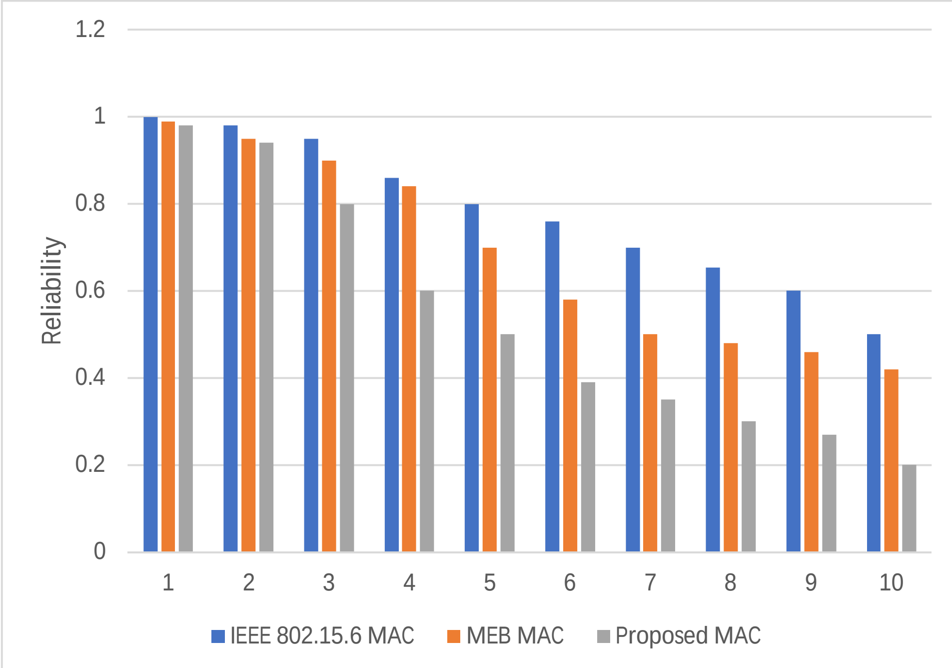

Figure.6(b):The reliability of the proposed MAC is compared with various indicators.

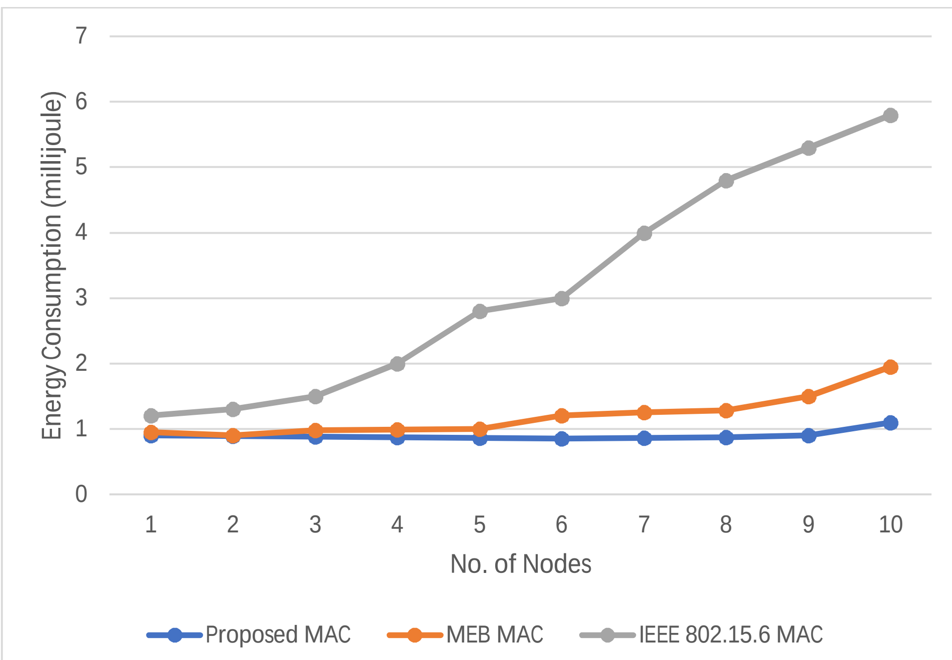

Figure.7(a): Comparing Proposed MAC with other Benchmarksaverage energy consumption for per kilobit data transmission.

The performance comparison of the proposed MAC with the IEEE 802.15.6 MAC and other benchmark MAC protocols is shown in Fig. 7. Comparing the proposed MAC protocol to the IEEE 802.15.6 MAC protocol and other MAC protocols, Fig.7(a) demonstrates that the proposed MAC protocol uses less energy per kilobit of data transmission. Because of dedicated allocation of slots in MAP and EAP, the power consumption of MAC requests is greatly reduced.

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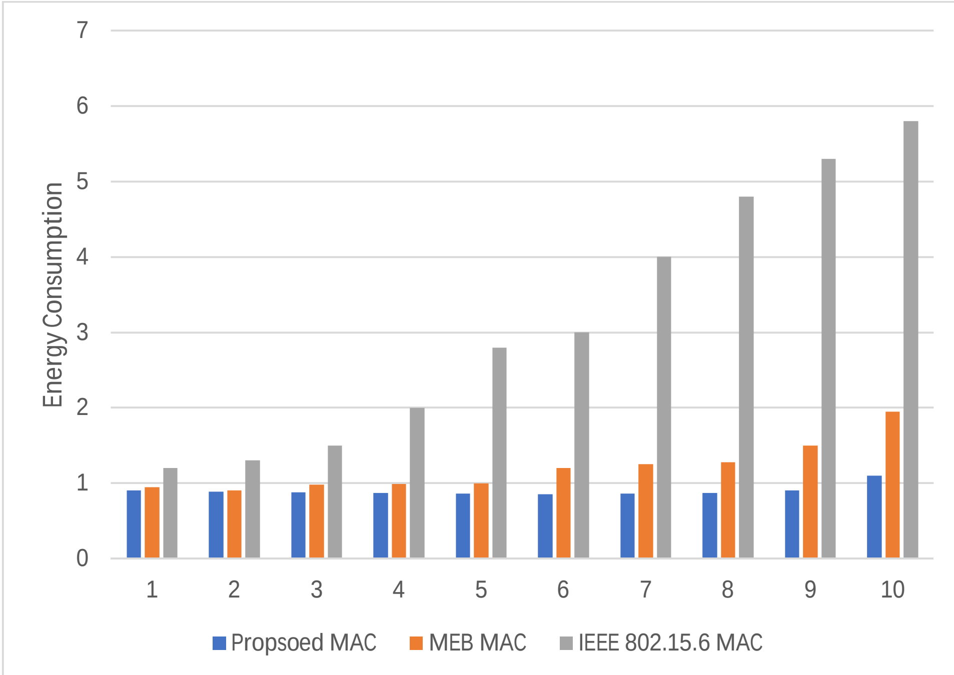

Figure.7(b): Comparing MAC requests Energy Consumption with several benchmarks.

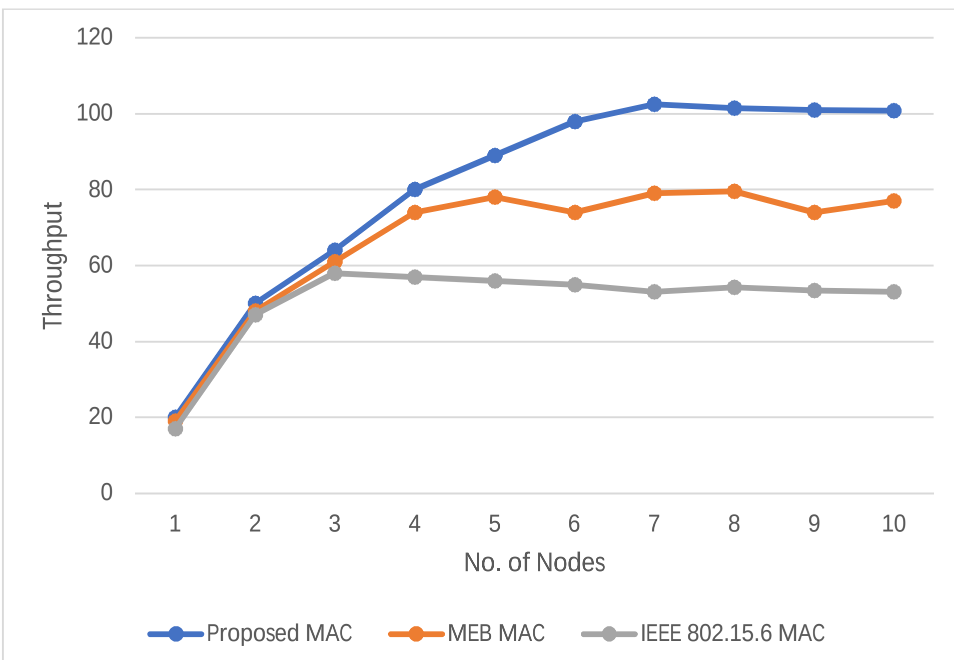

Figure.8(a): Comparing the overall Throughput of data transmission.

According to Fig.8, the suggested MAC protocol has a higher average throughput than IEEE 802.15.6 MAC protocols and other MAC protocols. As we add more sensor nodes up to a certain point, the network's throughput rises.
The network throughput is impacted for an increasing number of sensor nodes after a particular threshold. The likelihood of a collision occurring and the likelihood that a channel will be busy during periods of conflict are both increased by the presence of more sensor nodes.

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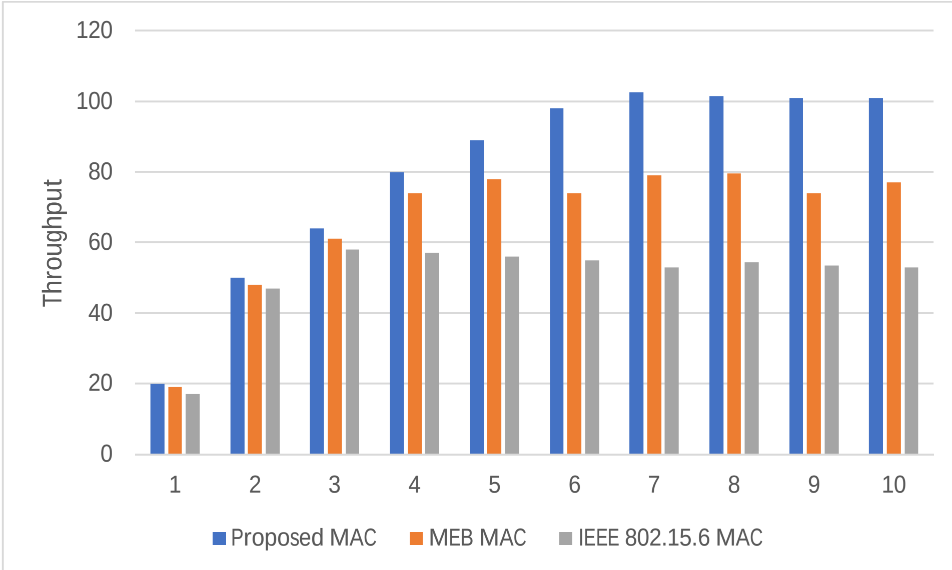

Figure.8(b): Comparing MAC requests Throughput with several benchmarks.

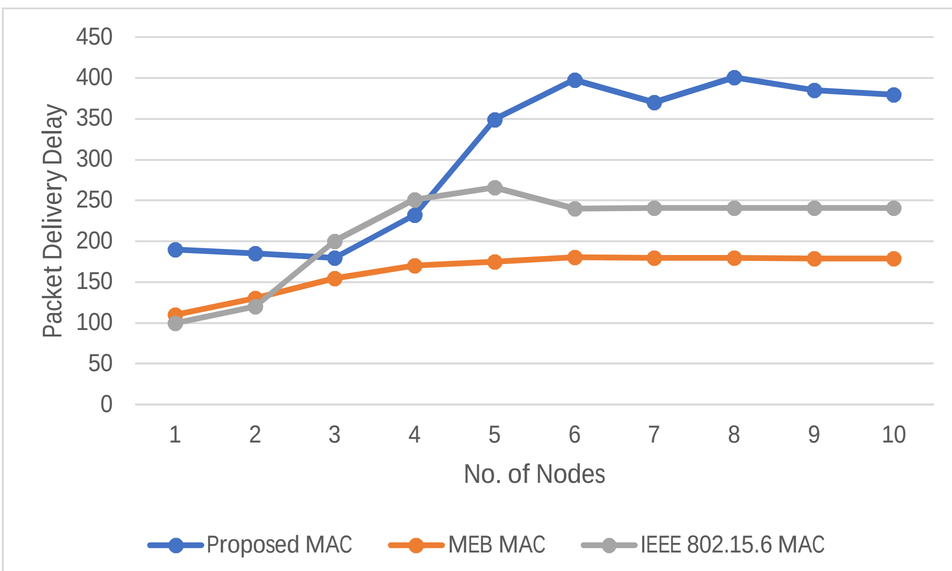

Figure.9(a):Comparing the Packet Delivery Delay of data transmission.

The above figures demonstrates that the proposed MAC offers significant advantages in comparison with reliability, energy consumption, and throughput, despite having a slightly greater average packet delivery latency than the standard IEEE 802.15.6 MAC and other existing MAC protocols. As a result, the suggested MAC's high packet delivery time is tolerable because it offers superior gains in other areas. For ten sensor nodes, Fig.8 compares that the performance of the MAC protocol which is proposed with other sensor prioritisation techniques in the SF structure of proposed protocol. When compared to IEEE 802.15.6 MAC, the suggested MAC's overall performance is noticeably improved.

The figure above shows that although the average packet switching delay is slightly longer than other MAC protocols and IEEE 802.15.6, the proposed MAC has significant reliability advantages such as pressure, energy consumption and distribution. Therefore, the high delivery time of MAC applications can be avoided as it provides the best results in other areas. For 10 sensor nodes as shown in Figure 1.

Figure 8 compares the performance of the proposed MAC with other priority assessment methods in the SF model. The overall performance (low power consumption, high efficiency) of the proposed MAC is significantly better compared to the IEEE 802.15.6 MAC.

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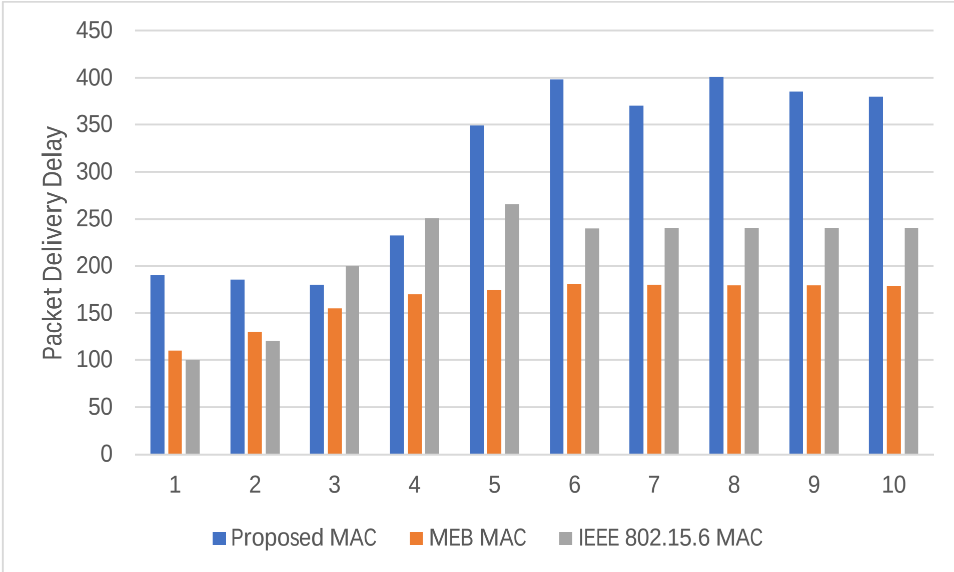

Figure.9(b): Comparison of MAC application packet delivery latency with various metrics.

Reliability is inversely correlated with PS and PGR, but it is proportionate to both BS and DTR. All of the BS, PS, DTR, and PGR parameters are proportional to throughput. Reduce the rate of packet loss is associated with failure by minimizing the size of sensor nodes. As a result, the network's speed, and dependability both modestly improve with an increase in buffer size. WBAN divides the SF structure into equal-length time periods. More data can be transferred quickly because smaller packets required fewer transmission slots.

V. CONCLUSIONS

In this work, we suggested a MAC protocol based on priority is totally devoted for the slot allocation for each sensor tool and a dynamic SF shape. each sensor tool is given a specific wide variety of EAP and MAP slots primarily based on its priority fee. every sensor device's priority price is established based on a selection of sensor metrics, inclusive of UP, packet introduction charge, buffer occupancy repute, records transmission rate, and packet length, the use of a mathematical version called CRITIC. in step with the simulation results, various MAC protocols which includes the IEEE 802.15.6 preferred are appreciably outperformed in phrases of network QoS and energy economic system.

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