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DESIGN OF IOT ENABLED OPTICAL WIRELESS SENSOR NETWORK WITH PRIORITY HANDLER USING DMAC PROTOCOL

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Abstract: ***This research work focuses to design optical wireless sensor network (WSN) which is enabled with internet of things service to share sensory information to IOT cloud. Directional media access protocol is used to establish communication link between nodes. To avoid network congestion here in this work an additional receiver is added to receiver side is proposed. Optical wireless communication is one of the most efficient, secure and high speed way of communication for short range applications. Directional MAC protocol used in present work is inspired with existing radio frequency protocol with some changes; data rates can ranges from kbps to thousands mbps and very low power consumption ranges in mW. According to proposed WSN model, first, time-slots are allotted for each node in vicinity and then transmission started and in case of nay prior node available its data is immediately transmitted to secondary receiver unit.***

Keywords: *IOT, DMAC Protocol, Random Access Protocol, Optical Wireless Sensor Network, Synchronization Frames.*

I INTRODUCTION

Due to low power consumption in milli-watts and high data transmission range around some Gbps [1] optical communication being one of the most important communication medium for short range applications. Optical communication based wireless sensor network provide physically secure and efficient way of data sharing. Optical communication sensor network mostly used for health monitoring system, real-time performance feedback by sensory system used in aircraft system to download and upload links. It is also useful for indoor hospitals [2], offices, cabins of airplane [3-5], water sensor network [6], houses [7] etc. To provide long distance communication most popular technique IOT (internet of things) is used to send data to cloud.

Internet of things is basically an internet service used to establish bidirectional communication in any wireless sensor network, things can be control wirelessly from anywhere with internet connectivity and things can be monitored from anywhere.

Directional wireless sensor networks are basically optics based wireless communication network used to provide high speed communication. A wireless sensor network consisted of different sensor nodes having multiple kind of sensors spaced from each other and situated in communication range. Sensor node are equipped with sensors, microcontroller or microprocessor, wireless communication transmitter receiver and power bank. In optical sensor network the prime medium of communication is light generated from LED or laser hence it has a limited range of data transmission and reception. Now with the advent of internet of things (IoT) it became easier establish communication link with unlimited range and worldwide data communication. In covid -19 pandemic IoT based patient monitoring systems are coming into fashion to provide wireless communication link between patient and his doctor. So in this research work combination of optical communication channel with internet based communication protocol is merged to mitigate the range of communication.

II RELATED STUDY

To enhance the performance of WSN in terms of number of successful transmission, network congestion, throughput and efficiency many research work has been done already. In [8] balance between energy efficiency and accuracy of detection is analyzed and MAC was proposed to improve efficiency. In [9] sensing order is optimized spectrum efficiency of energy are designed in which sequential sensing of the channel performed a node having

license channel for data transmission determined. In [10] sensing time and duration of transmission optimization are discussed and to achieve maximum network energy efficiency a sub-optimal algorithm is proposed. In [11] clustering mechanism based on CSS was proposed for wireless sensor network which basically decides the sleep and active time of nodes to improve energy consumption. Modified CSS scheme and detection probability improvement techniques are analyzed in [12] on the base of signal to noise ratio. In [13] to determine optimal number of cooperative SUs, transmission time and sensing, an iterative algorithm is introduced to maximize energy efficiency. In [14] IoT based wireless sensor network for smart agriculture application is designed to optimize energy efficiency and security.

Wireless sensor networks [15, 16] are made up of a large number of low-cost nodes with limited computing and communication capabilities. Sensor networks are wireless networks made up of small sensors that monitor physical or environmental factors like pressure, temperature, and noise level. Military, commercial, civil, vehicle tracking, intelligence, and habitat monitoring are some of the applications. Sensing, data processing, and transmission capabilities are all part of a sensor network. Data routing protocols attempt to reduce data duplication and hence increase energy lifetime.

The linked data issue is a unique feature of WSN. The data acquired by the nodes in the vicinity is relatively comparable, and changes in environmental values are relatively sluggish. These characteristics can be used to create energy-efficient data collection methods. The main consideration in a sensor network is to increase the lifetime of the network as well as the security of the system [16].

In wireless communication, Medium Access Control techniques are critical for channel access. Many challenges arise in the design of MAC protocols, such as the hidden terminal problem, collisions, overhearing, QoS, and so on. These issues have been the focus of research efforts.

Sensor nodes require a lot of energy since all of the sensors are powered by batteries. They are usually deployed in a remote location and are not recharged. As a result, the most critical need in MAC protocol design is energy economy. Collisions, data duplication, and idle listening are some more concerns that may take more energy. Due to collisions, retransmissions of packets require more energy. Idle listening wastes a lot of energy.

The main criterion in MAC protocol design is collision avoidance. A concealed terminal fault is also to blame for the accident. When two nodes are unable to hear each other and send packets to the same node at the same time, a collision occurs. MAC protocols are divided into three categories: CSMA-based protocols, TDMA protocols, and hybrid protocols.

III NETWORK ARCHITECTURE

In proposed wireless sensor network, two types of distinct nodes are arranged at different location in which 10 leaf nodes and one cluster head are taken. Nodes are equipped with LED as transmitter unit with power consumption 2uJ, photodiode as receiving unit with power consumption 1uJ, control unit and power supply. Both types of nodes are configured to transmit signal directionally using beams light with angle of divergence 10°, but field of view (FOV) of cluster head is much wide as it has five signal transmitter in ring type structure and a photodiode to receive information of leaf node as shown in figure 1. Cluster head is responsible to deal with traffic of network generated by different nodes and minimize cross talk and aggregate data. To solve the network congestion an additional photodiode is mounted to cluster head to accept data of leaf node having urgent need of data transmission as if it has prior sensory data.

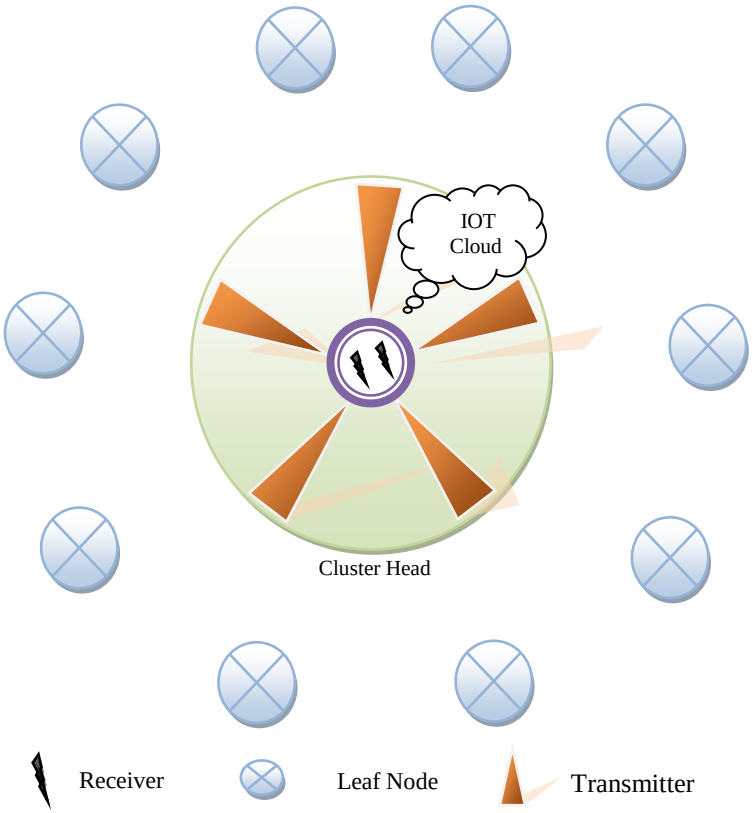


Figure 1 Architecture of Proposed IoT enabled WSN

As leaf nodes have narrow FOV, it is important to place them in such a manner to be line of sight (LOS). That means according to this structure a master-slave network architecture has developed. Leaf nodes are work as slave and cluster head serves as master node and capable of communicating all leaf nodes. Wireless sensor network parameters are tabulated below in table 1.

Table 1: WSN Parameters

S. No.	Parameter	Value
1	LED Wavelength	1.6um
2	Transmission Power	2uJ
3	Reception Power	1uJ
4	Number of Packets	100
5	No. of Nodes	10
6	No. of Cluster Head	1
7	Hop Length	1 m
8	Data rate	100Kbps
9	Voltage	5 Volts
10	Current	9 mA
11	Energy Consumed in Sleep Mode	1pJ
12	Power Consumption in Listening	8.5 nJ
13	Probability of Request of Data Transmission p0	1/10,1/9,1/8,....1/1
14	Window Size	1, 2 & 3

One of the essential feature designed and added to master unit that is internet connectivity with the aid of WiFi module which facilitate entire unit to send collected information of all nodes to cloud server. This modified feature is call IOT (internet of things) enabled wireless sensor network. Internet of things is basically provide limitless data transmission range; administrator can access data from anywhere where internet service is available.

IV SYSTEM DESIGN & ALGORITHM

The concept of DMAC protocol is introduced avoiding congestion by assigning time slot to each node attempting to send its data to cluster head (CH) in minimum number of synchronization frames (SFs). When cluster head detects signal transmitted by leaf nodes with its unique identification number (ID) then cluster head transmits an individual MAC address to identified node. After getting assigned leaf node stops retransmission request signal to CH. Now this process repeats again and again until request transmitted by leaf node becomes zero as shown in figure 2.

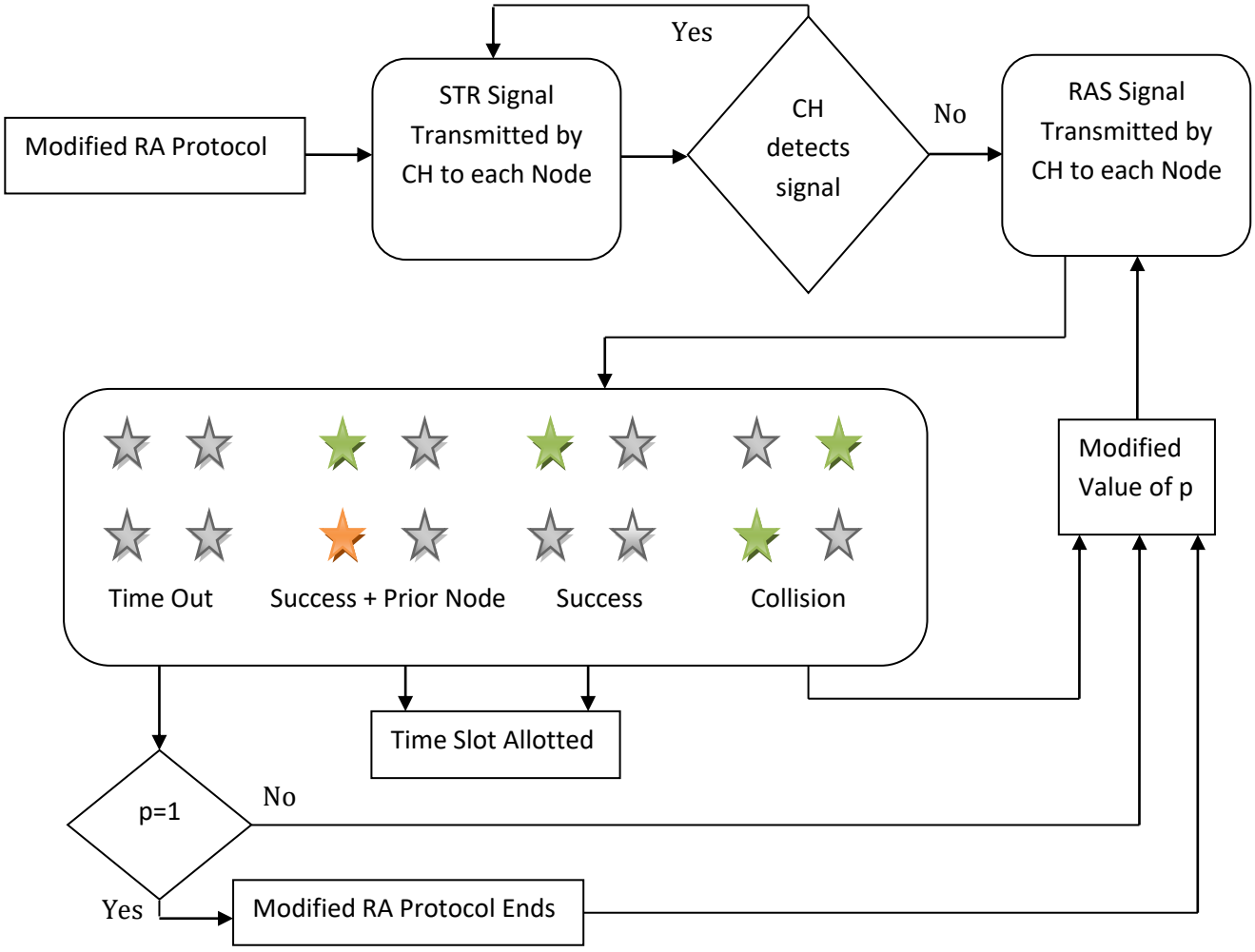


Figure 2: Flow Diagram of IOT enabled Modified DMAC Protocol with Priority Handler

In this proposed algorithm a random access protocol (RA) has been used to establish a communication network among nodes without any complexity and interrupt. A modification is done in basic model of DMAC protocol that is an addition of extra receiver to CH as a priority handler module to serve the nodes have highest priority to transfer data. In such a way number of collision avoided and network congestion reduces drastically.

According to RA protocol CH broadcasts a STR (stop transmission request signal) to all leaf nodes under its field of view so network stop working for a particular time till each node requesting get its individual time slots which is called time division multiple access (TDMA). In this work directional data conversion has been done so it is called direction TDMA. So in this situation all leaf nodes gets sleep mode but awaken. After a fixed time interval CH perform the broadcasts again and again till there is no signal received from leaf node in specified time interval. If CH gets request from priority node with a priority code then it serves related node.

Now, CH broadcasts a RAS (Random Access Synchronization) signal to FOV with an expected transmission request probability (p) value so using this value leaf nodes reply to CH. Now four condition may be occurred for specific time interval. In the flow chart gray colored star indicates no transmission, green colored star indicates transmission and orange colored star indicates priority of transmission.

(a) If no reply: then time out condition occurred. It means that there is no any node want to transmit data. And RA protocol ends.

(b) if priority node and one more node wants needs transmission then priori node will directly transmit its signal as communication done in CDMA (code division multiple access) mode and other node will get its time slot. And p value updated and again RAS signal transmitted.

(c) If single node replies to CH then it gets time successful and time slot allotted. And p value updated and again RAS signal transmitted.

(d) If more than one node replies simultaneously then its condition of collision. And p value updated and again RAS signal transmitted.

After time slotted allotted to each requesting node, time out condition reached then each node transmits data in its time slot. And after collecting data from leaf nodes, CH activates its IOT service and upload data to cloud server.

This modified scheme is analyzed and evaluated considering some input parameters value of p, p0 (initial value of p) and output metrics; network burst rate (NWBR), energy consumption, number of synchronization frames required to allot time slot and possibility of successful transmission.

V RESULTS & DISCUSSIONS

Probability of a successful packet transmission can be calculated as

$$S_n = np(1-p)^{n-1} \quad (1)$$

Where n is number of nodes requesting channel access and p is probability of transmission.

Initial probability of transmission is predicted 1/7. And now probability of successful transmission is calculated for each value of p0 and plotted below in figure 3. Leaf node unique IDs are Ids = {123 478 732 233 763 945 543 459 682 823} for 10 nodes in same order. Here Node with ID = 763 is assumed prior node.

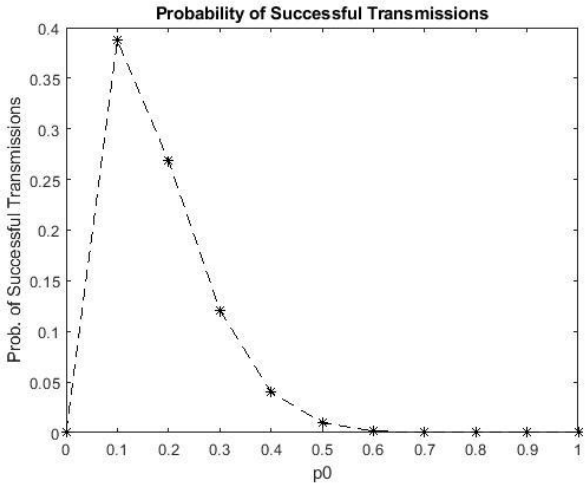


Figure 3 probability of successful transmission for initial p =1/7

If prediction of p value is optimal then lesser number of SFs are required to allot time slot. To get optimal value of p its updated again and again in each cycle during each RAS frame. To resolve network channel contention number of SFs can be calculated as

$$T_{SF} = \frac{1}{S_n} + \frac{1}{S_{n-1}} + \frac{1}{S_{n-2}} + \cdots\cdots\cdots\cdots \frac{1}{S_1} = \sum_{j=1}^{n} \frac{1}{S_j} \quad (2)$$

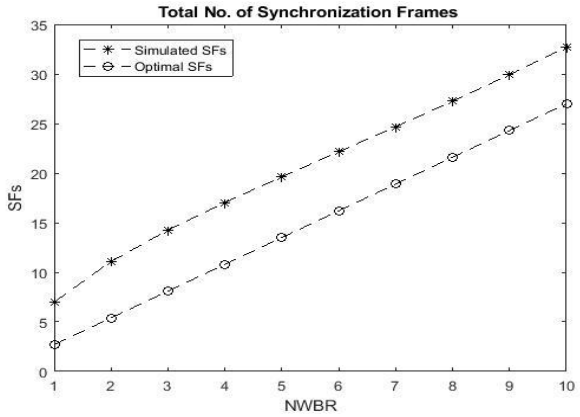
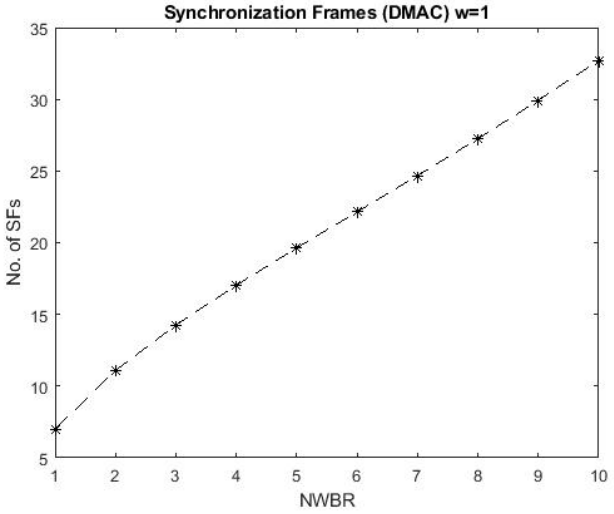


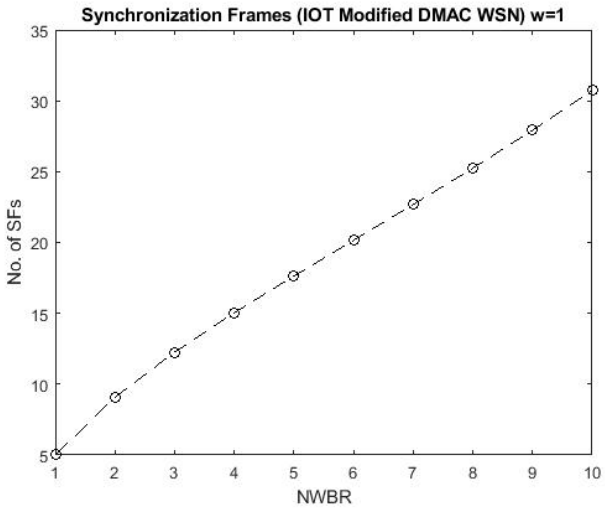
Figure 4 Total Number of SFs Theoretical and Practical

From figure 4, it can be observe that with increase in NWBR value, more number of SFs are required.

Total number of synchronization frames required to allot time slot to contending nodes simulated for DMAC protocol and IOT based Priority Hander DMAC protocol are shown in figure 5.



(a)



(b)

Figure 5 (a) DMAC WSN SFs for w=1 (b) Proposed IOT DMAC for w=1

Comparing figure 5(a) & (b) it is found that proposed WSN needs less number of frames to resolve congestion.

Optimization of performance of proposed WSN is basically minimizing RA time period which directly reduces the energy consumption required in communication. Hence initial energy wasted by CH is depends on algorithm and NWBR values which can be calculated as [17]

$$E_X^{CH} = \left(A_w(p_0)\right) = 5E_p(T + C) \quad (3)$$

Where p0 is initial value of p, w is window size of proposed algorithm, X is value of NWBR, number of normal LEDs are 5 to transmit signal by CH, T is timeout and C is collision occurred. And Packet energy can be calculated as in equation 4.

$$E_p = I * V * \frac{Number\ of\ 1\ bits}{B} \quad (4)$$

Where V=5 volts is voltage across LED, I=9mA is current flow through LED, $Number\ of\ 1\ bits$ is average number of '1' bits in packet which is 57. B is speed of communication and is 100kb/s [17]. Hence calculated E_p =25.7uJ.

The average energy [17] wasted by all sensor nodes can be calculated as

$$E_X^N = \left(A_w(p_0)\right) = E_p M_C \quad (5)$$

Where M_C denotes the total number of leaf nodes that are involved with causing a collision at the CH during a single SF.

Now, Energy loss function for each vales of NWBR can be defined as [17]

$$H\left(\lambda_1, \lambda_2, \lambda_3, \ldots\ldots\ldots \lambda_N, A_w(p_0,)\right) = \sqrt{\sum_{X=1}^{N} \lambda_X (E_X^T - O_X^T)^2} \quad (6)$$

Where N is the total number of sensor nodes in the network; O_X^T is the expected energy loss value.

The term $(E_X^T - O_X^T)$ decreases as NWBR value decrease due to in case one contending node is prior node having urgency of transmission. Figure 6 shows energy consumption calculated by energy loss function for basic DMAC WSN, which shows that is value of p0 is less, energy consumption is less but if it is minimum at initial value of p.

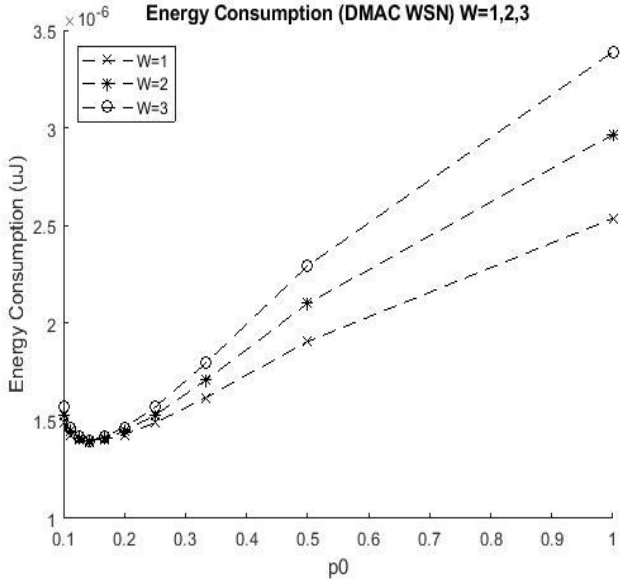


Figure 6 Energy Consumption for w=1,2,3 (Basic DMAC WSN)

Figure 7 show Energy Consumption in proposed IOT based priority handler DMAC protocol WSN model for different window size of algorithm w=1,2&3.

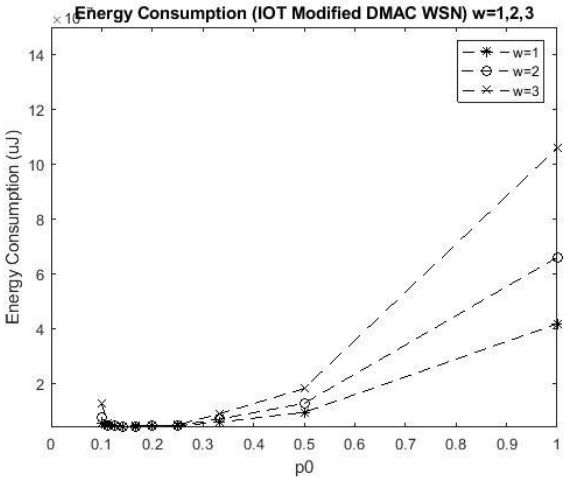
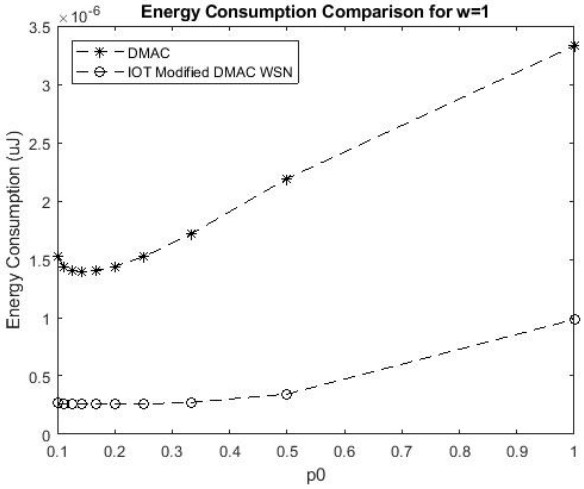
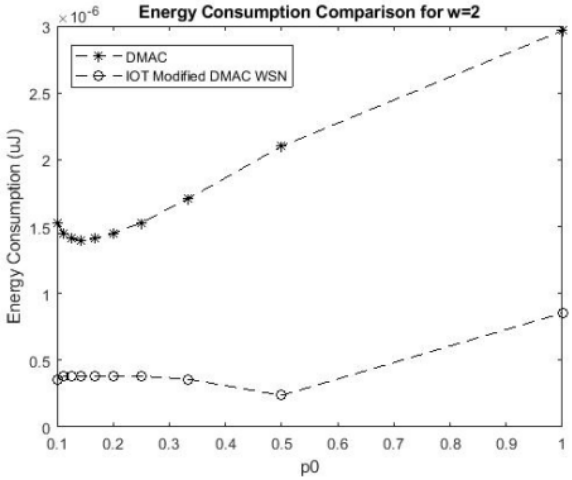


Figure 7 Energy Consumption for w=1,2,3 (IOT based Priority Handler DMAC WSN)

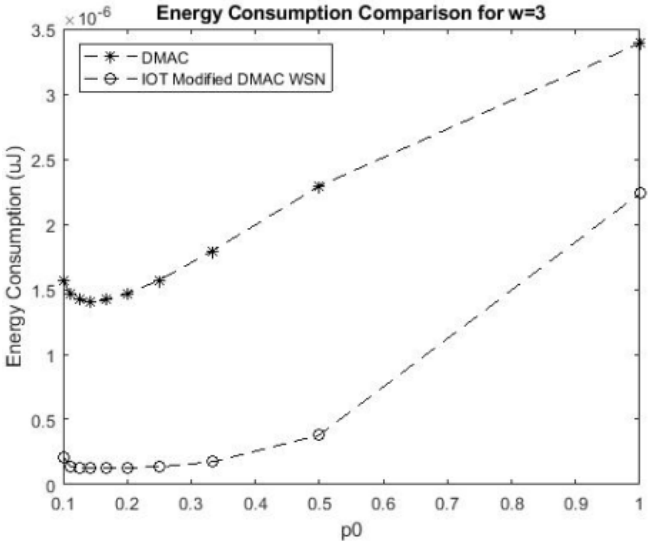
Figure 8 presents comparison of energy consumption of DMAC WSN and IOT enabled modified DMAC WSN for different window size.



(a)



(b)



(c)

Figure 8 Comparison of DMAC WSN and IOT enabled Priority Handler DMAC WSN

According the results of figure 8 it can be concluded that IOT based modified DMAC WSN consumes very less energy as compared to that of basic DMAC WSN protocol. The comparative analysis of proposed system with basic DMAC is shown in table 2 below

Table 2: Comparison of Basic and IOT based Proposed Energy Consumption for w=1

S. No.	p_0	DMAC WSN Energy Consumption (uJ) for w=1	IOT based DMAC WSN with Prior Node Handler Energy Consumption (uJ) for w=1
1	1/10	1.489	0.269
2	1/9	1.429	0.259
3	1/8	1.4	0.2586
4	1/7	1.39	0.2584
5	1/6	1.4	0.2584
6	1/5	1.43	0.2585
7	1/4	1.49	0.26
8	1/3	1.6	0.273
9	1/2	1.9	0.345
10	1/1	2.53	0.985

VI CONCLUSION

Study of DMAC protocol using RA protocol handler and priority handler for the nodes having urgency of data transmission is done in the present research work. This performance analysis is done on the MATLAB software version 2019a. MATLAB coding and graph plotting function are used to simulate proposed work is used. According to the results obtained from the simulation, concepts and theoretical analysis it is concluded that IOT based modified DMAC protocol for handling additional node which is basically prior node is performed better as compared to basic DMAC WSN

protocol in term of energy consumption and number of synchronization frames required.

From the analysis it is found that energy consumption is minimum for window size = 1 and comparative analysis of basic DMAC protocol WSN and Proposed IOT enabled modified DMAC protocol WSN with prior node handler, it is concluded that according to table 2 proposed system energy consumption is 84% less as compared to conventional DMAC protocol. Hence Proposed system is proved best for optimizing energy consumption, probability of successful transmission, number of synchronization frames required to avoid contention.

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