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Design and Implementation of QoS Aware Priority based MAC for Delay Sensitive Areas of WSN

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ABSTRACT

Networking is a trending research area where the various research took place. Diversified filed of the Network is Sensor Network, which is a centrally adopted due to features and flexibility of sensors. Various disciplines like a military, medical, forest, Industries, Health monitoring and more, where WSN is established. Sensors have various pitfalls like limited lifetime and Storage, installed in misanthropic environments. Frequently power up or replace an energy source is a crucial task. Data communication in WSN is possible in the MAC layer. MAC is responsible for node schedule and sensing task. Collision and retransmission also lead to waste of energy. Variety of MAC protocols are developed for various qualities of service factors like energy, latency, reliability, delay, jitter, etc., however, none of them are given a satisfactory result for various QoS parameters. To overcome some of the pitfalls we need to achieve various QoS parameters. In this Research MAC is designed with a priority mechanism over clusters. Data with the highest priority are sent without or with a very negligible amount of delay. Higher priority packets are transmitted before a no prioritized packet. Using various priorities, the node energy, low delay and high throughput are achieved over standard MAC Protocols.

Keywords - **Energy, Delay, MAC, Priority, Throughput, WSN**

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I. INTRODUCTION

Wireless Sensor Network is a Network of tiny, smart and intelligent devices called sensors or nodes. Sensors are made up of micro electromechanical tiny circuits with some sensing capacity. Sensors consist of a processing unit, Small amount of storage unit, Power Unit or Energy, Sensing unit and a transmission unit. Sensing circuit sense some information from the environment where it is installed. The sensed information is stored in a storage unit of a node,

After that a processing unit process the information and then, an informations are transfer to Sink node by the transmission or communication unit. The battery life of a sensor device is very limited due to some limitations of WSN. As it is installed in the unfriendly environment to charge a battery is not an easy task. The sensors sensing task are very expensive in terms of energy due to ideal listening and sensing. If the communication protocols are power efficient than the lifetime of a WSN can increase.

In Wireless Sensor Network Information's are handled by the two major mechanisms of WSN, that are Routing and Medium access control. A routing technique in WSN is responsible for transmitting data between sensors and the sink node/base stations. For routing purpose various protocols are used like RPL (Routing Protocol over Low-power and Lossy Networks), HEED - A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks for hierarchical routing. TEEN - Threshold Sensitive Energy Efficient sensor Network protocol: TEEN is proposed as a hierarchical routing protocol for time-sensitive applications and other protocols like APTEEN, LEACH, MMSPEED etc., and many more.

While MAC is responsible for Channel acquisition policies, Buffer Management, and etc., Various MAC protocols are developed by the Networking community. WSN MAC protocols are having various categories like Schedule based Protocols, Contention based Protocols, and Hybrid protocols. Schedule based protocols like LMAC, PRMAC, LEACH, Sender MAC, A MAC, RT MAC, etc. uses TDMA approach for the channel. While Contention-based MAC protocols have to pay the high cost for collision, Idle listening, and overhearing. It uses CSMA or CSMA/CA approach for channel acquisition. IEEE 802.11, WISE MAC, ER MAC, RL-MAC are contention based Protocols. Hybrid protocols use the combine TDMA and CSMA for the channel. ZMAC, QMAC, EE MAC are examples of Hybrid MAC Protocols.

In WSN each device share same medium for communication that's why we need efficient MAC too. The WSN research community has developed various MAC for WSN. Some of them look after energy while they compromise with the other quality of service factors. Some are designed for delay and throughput, but to achieve low delay they compromise with energy. And some of them are playing a significant role to reduce ideal listening, prone to overheating and etc., for increasing the network lifetime. Through There are more numbers of MAC are in existence, Very few of them has proved as a good MAC Protocols. The identification of good MAC are Energy efficiency, Low delay, Higher throughput, and Low latency are considered. Rather centrally focus on only this QoS parameter we need to achieve efficient delivery of data too. Efficient delivery of data means data delivery should follow some rules that minimize the energy and maximize the throughput and also considered the criticality of the data that can achieve using priority queues.

In this research, we analyze various MAC Protocols that are described in the next section and proposed a MAC by considering the priority of a date. The priority is set based on some regulations and threshold values.

The rest of this paper contains following content. Section II contains Related work done by the WSN Community. In section III, we describe our problem definition with its necessary details and also discuss the Proposed model. In section IV, Simulation Result and Performance are discussed. Finally, we conclude in section V.

II. RELATED WORK

In the year 2005, Yang Liu, I.. Elhanny and Hairong Qi [80] developed Q-MAC Protocol that minimizes the energy consumption in multi-hop WSN environment and offers QoS by Different Network services using priority mechanism. MAC support intra-node and inter-node arbitration. The intra-node packet scheduling is based on multiple-queuing architecture. It uses packet classification and weighted arbitration. The inter-node packet scheduling is based on a random access algorithm. MAC is compared with SMAC in the non-prioritized traffic scenario; when packets with different priorities are present, Q-MAC performs well in terms of latency and energy level is same as SMAC.

In 2006, Kien Nguyen, Thinh Nguyen et. Al, School of Electrical Engineering and Computer Science, Oregon State University, Corvallis, USA [77] developed PSIFT for WSN. A prioritized CSMA based MAC protocol which improves the performance of event-driven WSN by minimizing redundant reports of sensor nodes in proximity. PSIFT achieves low collision and shorter delay. PSIFT also reduce the latency compared to IEEE02.11MAC.

In 2007 A.M. Firoze, L.Y. Jun and L.M. Kwong, Department of Electrical Engineering, National University, Singapore [72]. Develop PRMAC protocol. PRMAC Protocol uses static priorities to an event. PRMAC Achieves delay, but sometimes not deal with the energy of a network.

In the year 2010 both eventual and J. Ben-Othman, PRiSM Laboratory, University of Versailles, 45 Avenue des Etas-Unis, 78000 Versailles, France developed EQMAC [74]. Energy efficient and Quality of service aware MAC. EQMAC is TDMA and CSMA based Hybrid concept. It differentiates between long and short message. It also uses the priority mechanism for higher prioritized data. It uses schedule and non-schedule scheme for data transmission for greater performance. It is derived from Classifier MAC and Channel Access MAC. EQMAC is highly energy efficient with heavy traffic load also. Compare to QMAC Latency is also decreasing when the priority mechanism is used.

In 2011 Jalel Ben-Othman, Lynda Mokdad, Bashir Yahya from France [75] developed energy efficient priority based MAC protocol for wireless sensor network known as PRIMA. PRIMA use the contention based and schedule based channel policy to communicate between nodes. Queuing model of PRIMA introduces four different queues to achieve Quality of Service. PRIMA protocol is compared with Q-MAC and provide better results in terms of Energy efficiency, Delay and packet delivery ratio.

In the year 2012 Kien Nguyen and Yusheng Ji [76] introduce an Asynchronous MAC protocol with QoS awareness in WSN terms as AQMAC. AQMAC adopted a receiver-initiated (RIMAC) transmission and provide a queuing mechanism for prioritized data. It simply divides priority into two queues like high priority data and low priority data. The queued packets are often concatenated into a bigger one before sending out in a burst. By queuing lower priority packets, AQ-MAC significantly saves the energy consumption caused by idle listening at senders. Moreover, by using the concatenation scheme AQMAC notably improves the latency performance as well as it reduces control overhead.

In the year 2014**, M. Yousof Naderi, Member, IEEE, Prusayon Nintanavongsa, Member, IEEE, and Kaushik R. Chowdhury, Member, IEEE [78]** developed a new MAC that is RFMAC protocol for WSN. RF Stands for Radio Frequency. RFMAC is A medium access control protocol for rechargeable sensor networks Powered by Wireless Energy Harvesting. RF-MAC protocol specifically addresses the problems of the joint selection of energy transmitters and their frequencies based on the collective impact on charging time and energy interference, setting the maximum energy charging threshold, requesting and granting energy, and energy-aware access priority. Simulation and test bed results reveal that RF-MAC largely outperforms the modified CSMA in both average harvested energy and average network throughput.

In the year 2017 **Ananda Kumar Subramaniam and Ilango Paramasivam [79]** introduce a new priority Based Energy-Efficient MAC Protocol for Wireless Sensor Network varying the sample Inter-Arrival Time is PRIN MAC. PRIN - PRIority in Node, using static priority in the source and intermediate node and priority among the node which is one hop from the sink node to achieve QoS in WSNs. PRIN MAC minimizes the energy consumption by considering two types of queues, high priority, and low priority. Nodes near by a source are considered as a high priority node and nodes near by receivers are considered as low priority nodes. PRIN MAC is compared with TMAC and SMAC that achieves energy efficiency comparisons to these two protocols, but throughput received with interference are not well as other parameters.

Wei Ye, John Heidemann, Deborah Estrin. (2002). An Energy-Efficient MAC Protocol for Wireless Sensor Networks. IEEE communication is Sensor MAC [10]. The basic design goal of SMAC is to reduce energy consumption and Support good scalability and collision avoidance. SMAC tries to reduce wastage of energy from all four sources of energy inefficiency, Collision – by using RTS and CTS, Overhearing – by switching the radio off when the transmission is not meant for that node, Control overhead – by message passing, Idle listening – by periodic listen and sleep. In exchange, there is some reduction in both per-hop fairness and latency. Periodic sleep leads to high latency.

Berkley Media Access Control (BMAC) is a MAC level protocol for Wireless Sensor Networks, which uses adaptive preamble sampling scheme. This technique consists of sampling the medium at fixed time intervals. The goals of BMAC protocol are low power operation, effective collision avoidance and efficient channel utilization at low as well as high data rate. BMAC can be scaled to a large network. BMAC is unable to provide multi-packet mechanisms like hidden terminal support, message fragmentation, and particular low power policy. **Ilker Demirkol, Cem Ersoy, and Fatih Alagöz, Bogazici University. (2006, April). MAC Protocols for Wireless Sensor Networks: A Survey. IEEE Communications Magazine[21].**

Asynchronous schedule MAC is developed by **Beakcheol Jang, Jun bum Lim and Mihali I. 2012. [73]** In AS MAC each node stores the wakeup scheduler of their neighbors and reduce overhearing, contention, and delay. ASMAC considerably reduce energy consumption while providing good delay and packet loss in comparison with existing MAC protocols. The two major drawbacks of ASMAC are: One is overhead for broadcast and another is it need to store one-hop neighbor table.

In 2011 Mohammad Arifuzzaman, Mohammad Shah Alam and Mitsuji Matsumoto , IEEE conference, CAP town, South Africa[81]. introduce Intelligent Hybrid MAC(IH MAC). Which works better without compromising with energy efficiency in high traffic load and use two types of scheduling like broadcast scheduling and link schedule. IHMAC combines the strength of CSMA and TDMA. As per the network traffic, it switches between broadcast schedule and link schedule. It uses RTS and CTS handshaking to minimize the transmission power. IH MAC achieves energy efficiency by minimizing the transmission power.

III. PROBLEM DEFINITION

After analysis of various CSMA based MAC Protocols, here we proposed a cluster-based prioritized MAC Protocol for Wireless Sensor Network achieves an end to end delivery of sensitive packets without delay using a priority-based algorithm. To improve the packet delivery ratio using queuing and station polling mechanism, And achieve high throughput with energy efficiency.

3.1 Model and Assumption

Among this various critical sector of WSN, we design a model for an environment like military. For this proposed MAC protocol, we consider the military environment where some nodes are static and some nodes are dynamic on a field. Like there is one base station called the main control room and other nodes are sink nodes or the sensor nodes. A Sink nodes are the nodes with high capacity that can become head of the clusters, here access points are sink nodes and they are Static. All the military man or tank etc, can be considered as dynamic nodes that are movable and consider as sensor nodes that since the information and send to nearest sink nodes.

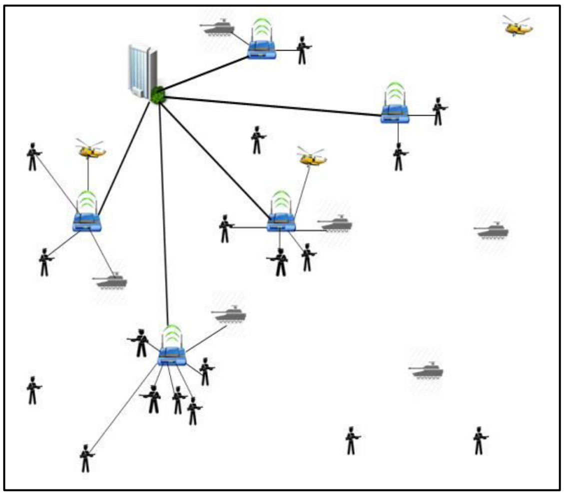

Figure: Model Assumption for proposed MAC

3.2 Proposed Methodology

To design and develop a protocol for cluster-based priority MAC we consider the queuing mechanism based on a priority of packets sent by the nodes. In proposed model we develop two types of queues. One for prioritized data and another for normal data.

First, we design priority identification algorithm and then we design queue selection algorithm. As here we have a cluster based network, we need polling scheme for nodes. In our research, we design two types of nodes. Some are static and others are dynamic nodes. Dynamic nodes change their locations frequently. As node is dynamic according to its location it join the nearest cluster by using a polling scheme. One cluster can have various nodes in its network and there is one head node which is static.

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3.3 Mathematical Model for Assigning a Priority Queue.

Here we have two types of Priority queues, that Serves different packets coming from different nodes, Where the sink has infinite buffer capacity. Packets arrive at respective queues in random fashion μ. Let, N_K denote the number of packets belonging to the N^{th} queue., Where K=1,2,3,......... Priorities are accordingly $Pr[N_K]$ = K,K+1,K+2,K+3....K+n. Where K=1. Let P_K denotes the number of packets arrived at P^{th} queue where K=packets with threshold value $P_n(Th)$ + $P_{n+1}(Th)$+ $P_{n+2}(Th)$........ $P_{n+n}(Th)$, Where n=1.

First, we assume that both the queues are empty, therefore when a packet arrives at the beginning then serve it to N_K. If a number of packets generated by nodes in a network reach up to the threshold value then serve it to P_K. So, a total number of packets into a network that is going to serve to respective queues are N[n]+P[n].

The probability Q_q is : Packet served at normal queue and the probability P_q is : packets served at priority queue , Where $Q_q + P_q = 1$. finally, the newly arrived packets are served as per the priority of the packets in a network. Only the packet at head position of a queue is allowed to served in a respective queue other packets in a queue has to wait for their turn. And if the interval has arrived in a transmission of packets then need to add interval time i_t to calculate a transmission time T_t of the packets

Packet Service Process: In Proposed model, there is an only single server that provides service to all the packets in a network. A packet at the head position in Priority queue is served one by one without a wait. When all the packets of priority queue are served and queue gets empty the packet at head position of normal priority are served. As per the above rules Queue with priority gets the Pre-emptive service over the normal queue.

3.4 Proposed Algorithms

Algorithm 1: Priority Identification Algorithm

N_H - Head Nodes or Access Points/AP

N_C - Child Nodes

S N_H – Set of Head Nodes

S N_C - Set of Child Nodes

STEP 1: N_H receives packets from N_C.

STEP 2: Node check whether a Packet type is Data Packet or Information/ Acknowledgment frame.

STEP 3: If the packet is Data Packet then
Check its priority
If Packet has a higher priority, then
Store it in a High Priority queue and go to step 4.
Else
Store it in normal Priority and go to step 5

STEP 4: Forward the packet of a higher priority queue to BS. And wait for an acknowledgment.

STEP 5: Wait for a turn to transmission slot.

STEP 6: If time slot is allocated to Normal queue. Then forward Packets from normal queue.

STEP 7: Stop

Algorithm 2: Queue Selection Algorithm

ΔH_Q – Higher Priority Queue

ΔN_Q – Normal Queue

T – Traffic, T_P – Prioritized traffic, T_N – Normal Traffic

D_T – Delay Time

$D_P/_T$ – Transmission Time of data into medium

P_T – Propagation Time

D_{ET} – End to End Delay Time

T_{PT} – Processing Time of each node

H – Number of Hopes

O_H - Overhead at each Hop

S – Station or Node,

Si Source Node,

Sj Destination Node

C – Cluster, N – Nodes

STEP 1 – Initialize above notation by its default value.

STEP 2 - While Si sends T to station Sj, via cluster C.

STEP 3 - If T = T_P then
"Put T_P into ΔH_Q "
Else
"Put T_N into ΔN_Q"
End If

STEP 4 – Observation of Delay time D_T for ΔH_Q
While transmitting from I to J
Calculate R(Result) = D_T/T_P.

STEP 5 - If R ∈ ΔH_Q , then
Calculate D_{ET}(End to End delay time for Priority based Traffic)
= $N^* D_P/_{T(s)} + T_{PT} + R + (N^* O_H)$
Else If R ∈ ΔN_Q, then

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Calculate D_{ET}(End to End delay time for Normal Traffic)

$= N^* D_P/Ts + T_{PT} + N_{QDELAY} + T_P + R + (N^* O_H)$

End If

STEP 6 – End While

Algorithm 3: Station Polling Algorithm

Poll Activity – An activity carried out by Access Point That sends a contention frame to a secondary polled node.
Forward Activity – AP has Packets in its buffer for the destined node. AP forwards data packets to the destination node are known as a forward activity.

N_H - Head Nodes or Access Points/AP

N_C - Child Nodes

$S N_H$ – Set of Head Nodes

$S N_C$ - Set of Child Nodes be

T – Transmission

T_R – Transmission Range

In a network, there must be $S N_C > S N_H$ and $T_R (N_C) < T_R (N_H)$

Each $N_c \in \exists N_H$

s =Contention Free Period

STEP 1: In a network, it verifies $S N_C > S N_H$ and $T_R (N_C) < T_R (N_H)$ and $N_c \in \exists N_H$ then at a beginning of CFP, N_H transmit a beacon frame to all its $N_c(i)$.

STEP 2: After Receiving a beacon all $SN_C \in$ BSS, set their NAV and T = NULL in CFP.

STEP 3: N_H initiates its Polling Activity to each N_c and Send frames that contain Data + CF.

STEP 4: Polled station waits for a SIFS.

STEP 5: If a Polled station has a data to send then it sends Frame to N_H else it reply with NACK and sleep for a Time.

STEP 6: N_H receives a Frame and checks whether it is Data frame or Acknowledgement frame.

STEP 7: If it is a Data frame then Check its Priority and buffer them accordingly else Poll the next station for Data.

STEP 8: Repeat steps 3 to 7 for each station until CFP ends.

STEP 9: Exit

Based on above algorithms we develop Cluster based prioritized MAC. The next section describes the simulation setup and results by comparing existing MAC protocols with proposed MAC protocol.

IV. Simulation Result and PERFORMANCE EVOLUTION

4.1 Energy calculation, Delay Calculation, and Throughput Calculations

Transmitted Packets in a network

$(T_P) = Byte_s * 1024(Bytes)) *100(I_T)) / N * 10$(estimated transmitted Packets)

Where,

T_P - Transmitted Packets in a network, $Byte_{sec}$ - Bytes transmitted in particular time(sec), I_T - Interval time, N- Number of Nodes.

Received Packets in a Network $(R_P) += R_{PT} / N * 10$(estimated transmitted Packets)

Where,

R_P- Received Packets in a Network, R_{PT} - Packets received in particular Time period, N- Number of Nodes

Energy Calculation = $I_E + A_E + P_E$

Where

I_E - Idle Energy, A_E - Amplification energy, P_E - Energy for process

Average Delay (D) = $(\sum \text{Packet } R_T - \sum \text{Packet } T_T) + I_T$

Where,

T_T - Packet Transmission Time in Sec, R_T - Packet Received Time in Sec, I_T - Interval time

Throughput = $\sum P_T(Sec) - \sum P_R(Sec)$

Where,

$P_T(Sec)$-Number of packets transmitted in sec, $P_R(Sec)$-Number of packets Received in sec

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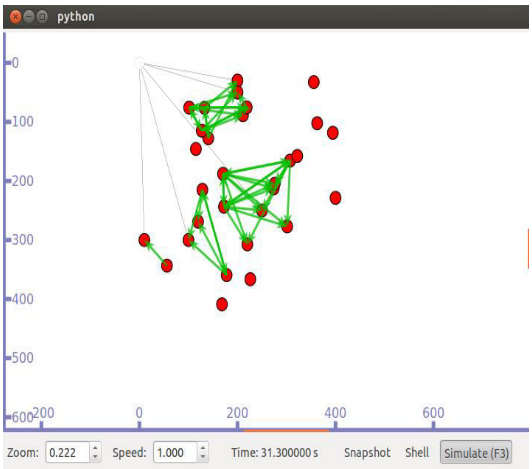
4.2 Simulation Parameter

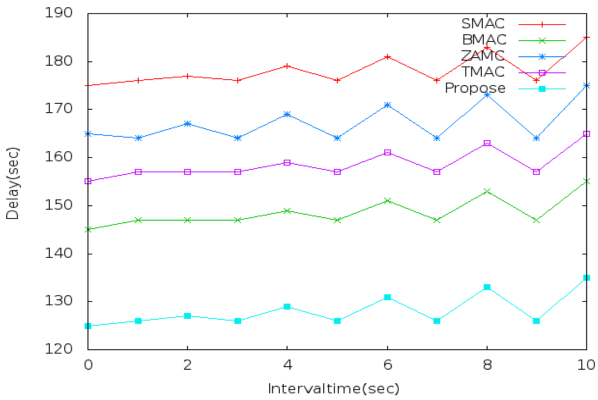
Parameter Name	Parameter Value
Simulator	NS3
Types of Node	1. Station Node 2. Access Point
Number of station Nodes	30
Number of Access Points	5
Nature of Environment	Hybrid (Static & Dynamic)
Number of Queues	2
Types Queues	High Priority Low Priority
Size of Network	500*500 Square meter
Packet Size	1024 Bytes
Default Delay	6560 NanoSec
Interval time	1.0 ms
Packet Size	1000 bytes
Total Packet in a network	10*Number of nodes
Access Channel	CSMA
Total Energy	300 J
Physical Layer Model	YanswifiModel

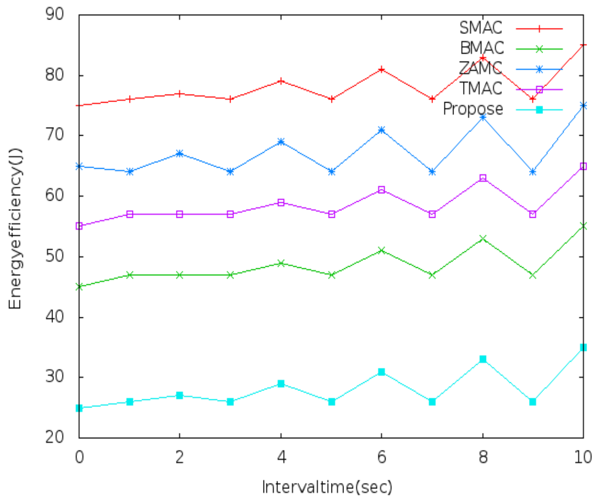
4.3 Simulation Result

Simulation result based Comparison of Existing protocols with our protocol (Proposed Protocol, SMAC, BMAC, TMAC, ZMAC)



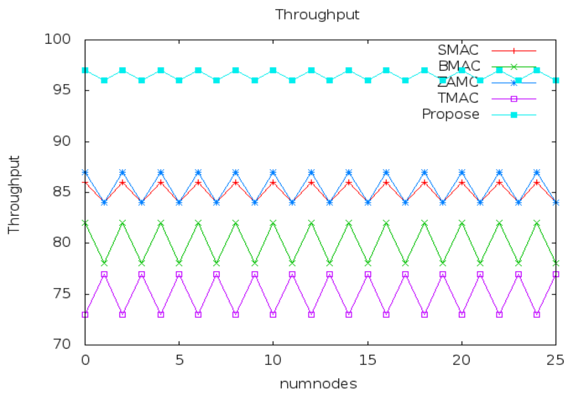
1. Implementation of heterogeneous network with static and dynamic nodes that communicate with each other





2. Delay Comparison of Cluster-based Prioritized MAC with other MAC.

3. Comparison of Cluster-based Prioritized MAC with other MAC in terms of energy



4. Throughput Comparison of Cluster-based Prioritized MAC with other MAC

Comparision of above Graphs

Protocol	Channel	Energy Efficiency	Delay Sensitive	Throughput Aware
SMAC	CSMA	Low	Low	High
BMAC	CSMA / TDMA	High	Low	Medium
ZMAC	CSMA / TDMA	Medium	Medium	High
TMAC	CSMA	High	Medium	Low

V. CONCLUSION

Proposed MAC result proved that for any dense network like a military application or any delay sensitive area can use prioritized Cluster based MAC protocol to reduce the delay and save energy. In this research, we analyze various Good MAC Protocols and compare them with proposed MAC for Quality of services like Energy Efficiency, Delay, and Throughput.Our MAC introduces efficient energy with a reduced end to end delay as it transmits data without additional delay and also deals with the problem of low buffer capacity by implementing various types of queues. Our MAC is developed in NS3 and could result in a better life of a network with achieved quality of services than SMAC, BMAC, TMAC, and ZMAC.

Reference

[1] Ajith Kumar S., Knut Øvsthus, Lars M. Kristensen - An Industrial Perspective on Wireless Sensor Networks - A Survey of Requirements, Protocols, and Challenges, *IEEE communication survey and Tutorials, Accepted for Publication(1st Review version)-2014*

[2] Khemapech, I. Duncan, and A. Miller, "A survey of wireless sensor networks technology," *in Proceedings of the 6th Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting, 2005*

[3] Koubaa, A., Alves, M., Tovar, E., Lower Protocol Layers for Wireless Sensor Networks: A Survey. *IPP-HURRAY Technical Report, HURRAY-TR-051101. 2005.*

[4] Murat DENER, ÖmerFaruk BAY- Medium Access Control Protocols For Wireless SensorNetworks: Literature Survey, *Gazi University Journal of Science, GUJ Sci,25(*2*):455-464(2012)*

[5] Pei Huang, Li Xiao, Senior Member, IEEE, SoroorSoltani, Student Member, IEEE, Matt W. Mutka, and Ning Xi, Fellow, IEEE - The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey, *IEEE Communications Surveys & Tutorials, Vol. 15(* 1)*, First Quarter 2013 101*

[6] A.WooandD.Culler. A Transmission Control Scheme for Media Access in SensorNetworks. In *ACM MobiCom, 2001*

[7] F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," *IEEE Commun. Magazine., vol. 40(*8)*, pp. 102–114, 2002.*

[8] Heena Ansari And Mohammad SarfuddinKhatib - A Survey Of Mac Protocol For Broadcast Problem In Wireless Sensor Network, *IOSR Journal of Computer Science(IOSR-JCE)e-ISSN:2278-0661,p-ISSN: 2278-8727PP 20-23*

[9] Yang Xiao, Member, IEEE, and Jon Rosdahl, SeniorMember, IEEE - Throughput and Delay Limits of IEEE 802.11, *IEEE communications letters, vol. 6(8), august 2002*

[10] Wei Ye, John Heidemann, Deborah Estrin – An Energy-Efficient MAC Protocol for Wireless Sensor Network, *IEEE INFOCOM 2002*

[11] Hon Sun Chiu, Kwan L. Yeung, and King-Shan Lui- J-CAR: An Efficient Joint Channel Assignment and Routing Protocol for IEEE 802.11-Based Multi-Channel Multi-Interface Mobile Ad Hoc Networks, *1706 IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 8*(4)*, APRIL 2009*

[12] Ahmad Abed Alhameed Alkhatib and Gurvinder Singh Baicher- MAC Layer Overview for Wireless Sensor Networks, 2012 *International Conference on Computer Networks and Communication Systems (CNCS 2012) IPCSIT vol.35(2012) © (2012) IACSIT Press, Singapore*

[13] Prof. Urmila A. Patil, Smita V. Modi, Suma B. J.-A Survey: MAC Layer Protocol for Wireless Sensor Networks, *International Journal of Emerging Technology and Advanced Engineering,(ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3*(9)*, September 2013)*

[14] AnisKoubâa, M. A. (2005). Lower Protocol Layers for Wireless Sensor Networks: *A Survey. Polytechnic Institute of Porto, Portugal.*

[15] Bhaskar Bhuyan1, H. K. (2010). Quality of Service (QoS) Provisions in Wireless Sensor Networks and

Related Challenges. *Scientific Research, October 2010.*

[16] Chu, Y. (2013). Application of Reinforcement Learning on Medium Access Control for Wireless Sensor Networks. *The University of York, Department of Electronics.*

[17] EkbataniFard, G. (2011). Multi-channel Medium Access Control Protocols for Wireless Sensor Networks: A Survey. *Islamic Azad University, Department of Computer Engineering, Guilan, Iran.*

[18] AykutVigited, ozlemDurmaz, and CemErasory (2011). QoS-aware MAC protocols for wireless sensor networks: A survey. *ELSEVIER, 1982–2004.*

[19] Neha Trivedi, Gkumar, and TeenaRaikwar(2013). Survey on MAC Protocol for Wireless Sensor Network. *International Journal of Emerging Technology and Advanced Engineering, 3 (2).*

[20] Pan, H. a. (2008). MEDIUM ACCESS CONTROL IN WIRELESS SENSOR NETWORKS. *Nova Science Publishers.*

[21] Pranav Pawar (2014). Green and Secure Medium Access Control. *ALBORG UNIVERSITET, Denmark.*

[22] Rajesh Yadav, S. V. (2009). A SURVEY OF MAC PROTOCOLS FOR WIRELESS SENSOR NETWORKS. *UbiCCJournal, 4 (3).*

[23] Umesh Kumar Singh*1, K. C. (2012). Study and Analysis of Reliable MAC Protocols for Wireless Sensor Networks. *International Journal of Computer Science and Information Technologies, Vol 3, 3884-3887.*

[24] Jian-ha wang and Yan yu (2013). A High Throughput MAC Protocol for Wireless Sensor Networks in Surveillance Applications. *JOURNAL OF NETWORKS, 8.*

[25] Zheng Teng, K.-I. K. (2010). A Survey on Real-Time MAC Protocols in Wireless Sensor Networks. *Scientific Journal, 2, 104-112.*

[26] Ceken, C. (2007). An energy efficient and delay sensitive centralized MAC protocol for wireless sensor networks. *Science Direct, Elsevier, 20-31.*

[27] Ilker Demirkol, Cem Ersoy, and Fatih Alagöz, Bogazici University. (2006, April). MAC Protocols for Wireless Sensor Networks: A Survey. *IEEE Communications Magazine.*

[28] L. Mokdad a, J. Ben-Othman b, B. Yahya c, S. Niagne c. (2014). Performance evaluation tools for QoS MAC protocol for wireless sensor networks. Ad Hoc Networks, *Elsevier, 86-99.*

[29] Messaoud Doudou, Djamel Djenouri b, Nadjib Badache, Abdelmadjid Bouabdallah. (2014). Synchronouscontention-based MAC protocols for delay-sensitive wireless sensor networks: A review and taxonomy. *Elsevier, 172-184.*

[30] Mounib Khanafer, Mouhcine Guennoun, and Hussein T. Mouftah. (2014). A Survey of Beacon-Enabled IEEE 802.15.4 MAC Protocols in Wireless Sensor Networks. *IEEE COMMUNICATIONS SURVEYS & TUTORIALS , 16 (2).*

[31] Myounggyu Won, Member, IEEE, Taejoon Park, Member, IEEE, and Sang H. Son, Fellow, IEEE. (2014). Asym-MAC: A MAC Protocol for Low-Power Duty-Cycled Wireless Sensor Networks with Asymmetric Links. *IEEE COMMUNICATIONS LETTERS, 18 (5).*

[32] Pei Huang, Li Xiao, Senior Member, IEEE, Soroor Soltani, Student Member, IEEE, Matt W. Mutka, and Ning Xi, Fellow, IEEE, (2013). The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey. *IEEE COMMUNICATIONS SURVEYS & TUTORIALS , 15 (1).*

[33] Ranjana Thalore∗, Jyoti Sharma, Manju Khurana, M.K. Jha. (2013). QoS evaluation of energy-efficient ML-MAC protocol for wireless sensor networks. *International Journal of Electronics and Communications (AEÜ), Elsevier, 1048-1053.*

[34] Taejoon Kim, Member, IEEE, David J. Love, Senior Member, IEEE, Mikael Skoglund, Senior Member, IEEE, and Zhong-Yi Jin, Member, IEEE. (2015). An Approach to Sensor Network Throughput Enhancement by PHY-Aided MAC. *IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, 14 (3).*

[35] Wee Lum Tan∗, Wing Cheong Lau, OnChing Yue. (2012). Performance analysis of an adaptive, energy-efficient MAC protocol for wireless sensor networks. *Elsevier, 504-514.*

[36] Xenofon Fafoutis, Alessio Di Mauro, Madava D. Vithanage, Nicola Dragoni. (2015). Receiver-initiated medium access control protocols for wireless sensor networks. *Computer Networks, Elsevier, 55-74.*

[37] Y.Z. Zhao a, M. Mab, C.Y. Miao a, T.N. Nguyen. (2010). An energy-efficient and low-latency MAC protocol with Adaptive Scheduling for multi-hop wireless sensor networks. *Elsevier, 1452–1461.*

[38] Ying Lin, RadimBartos. (2014). A survey of protocols for Intermittently Connected Delay-Tolerant wireless

sensor networks. Journal of Network and Computer Applications, *Elsevier, 411-423.*

[39] Yishan Su, Yibo Zhu, Haining Mob, Jun-Hong Cui, Zhigang Jin-a. (2015). A joint power control and rate adaptation MAC protocol for underwater sensor networks. *Ad Hoc Networks, Elsevier, 36-49.*

[40] Adebayo Segun, Akinwunmi A.O, Ogunti E.O. (2015). A Survey of Medium Access Control Protocols in Wireless Sensor Network. *International Journal of Computer Applications, 116.*

[41] Shekhar Kumar, Praveen Sah. (2015) A Survey on Energy Efficient Protocols for Wireless Sensor Network. *International Journal of Computer Applications, 120.*

[42] Akshay Sharma, Kunal Goel, Amit Kumar Bindal. (2015). Energy Efficient Scheme for Heterogeneous Wireless Sensor Networks: Research and Challenges. *International Journal of Computer Applications, 120.*

[43] Hemant Sethi, Devendra Prasad, R. B. Patel. (2011). EIRDA: An Energy-Efficient Interest based Reliable Data Aggregation Protocol for Wireless Sensor Networks. *International Journal of Computer Applications, 22.*

[44] Isha Batra, Ritu Malik, Meenakshi Mittal. (2010). Energy Efficient MAC protocols for Mobile Sensor Networks. *International Journal of Computer Applications, 1.*

[45] J.Vidhya, P.Dananjayan. (2010). Analysis of Cooperative STBC MIMO Transmissions in WSN using Threshold Based MAC Protocol. *International Journal of Computer Applications , 3.*

[46] Khushboo Gupta, Vaishali Sikka. (2015). Design Issues and Challenges in Wireless Sensor Networks. *International Journal of Computer Applications, 112.*

[47] Manjusha Pandey, Shekhar Verma. (2011). MAC LAYER PERFORMANCE: STUDY AND ANALYSIS FOR DIFFERENT MOBILITY CONDITIONS IN WSN. *International Journal of Wireless & Mobile Networks, 3 (6).*

[48] Ms. Sandeep Kaur, Ms. Sukesha Sharma. (2013). Comparative Study of Queen-MAC, TC-MAC and OD-MAC Protocols in Wireless Sensor Networks. *International Journal of Software and Web Sciences (IJSWS).*

[49] Neetu Kumari, Nikita Patel2 Satyajit Anand, Partha Pratim Bhattacharya. (2013). Designing Low Power Wireless Sensor Networks: A Brief Survey. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2 (9).*

[50] Radosveta Sokullu, Eren Demir. (2015). A Comparative Study of MAC protocols for Linear WSNs. In P. Computer (Ed.), *The 6th International Conference on Ambient Systems, Networks, and Technologies (pp. 492 – 499). ScienceDirect, ELSEVIER.*

[51] S.Muthukarpagam,V.Niveditta,S.Neduncheliyan. (2010). Design issues, Topology issues, Quality of Service Support for Wireless Sensor Networks: Survey and Research Challenges. *International Journal of Computer Applications, 1.*

[52] Senthil, Bifrin Samuel. (2014). Energy Efficient MAC Protocol for Wireless Sensor Networks Using Multihop Optimization. 2014 *International Conference on Innovations in Engineering and Technology (ICIET'14). 3. K.L.N. College of Engineering, Madurai, Tamil Nadu, India: International Journal of Innovative Research in Science, Engineering, and Technology.*

[53] Shekhar Kumar, Praveen Sah. (2015). A Survey on Energy Efficient Protocols for Wireless Sensor Network. *International Journal of Computer Applications, 120.*

[54] Shruthi B S1, Shaila K2, Venugopal K R3, L M Patnaik4. (2015). The Paradigm of Major Issues and Challenges in Wireless Sensor Networks. *International Journal of Advanced Research in Computer Science and Software Engineering, 5 (3).*

[55] Swati Sharma, Dr. Pradeep Mittal. (2013). Wireless Sensor Networks: Architecture, Protocols. *International Journal of Advanced Research in Computer Science and Software Engineering, 3 (1).*

[56] VAHID AYATOLLAHITAFTI, MD ASRI NGADI, AND JOHAN BIN MOHAMAD SHARIF. (2015). REQUIREMENTS AND CHALLENGES IN BODY SENSOR NETWORKS: A SURVEY. *Journal of Theoretical and Applied Information Technology, 72.*

[57] Arvind Kakria And Trilok Chand Aseri, Ph.D. (2014). A Survey on Asynchronous MAC protocols in Wireless Sensor Networks. *International Journal of Computer Applications (0975 – 8887) , 108 (9).*

[58] B. Rajesh Shyamala Devi and A. George. (2015). HYBRID CSMA/CA-TDMA BASED MAC PROTOCOLS FOR WIRELESS SENSOR NETWORKS. *ARPN Journal of Engineering and Applied Sciences, 10 (4).*

[59] Bhavana Narain, Anuradha Sharma, Sanjay Kumar and Vinod Patle. (2011). ENERGY EFFICIENT

MAC PROTOCOLS FOR WIRELESS SENSOR NETWORKS: A SURVEY. *International Journal of Computer Science & Engineering Survey (IJCSES), 2 (3).*

[60] Korhan Cengiz and Tamer Dag. (2015). A review on the recent energy-efficient approaches for the Internet protocol stack. Cengiz and Dag EURASIP Journal on Wireless Communications and, Springer Open Access.

[61] Lujuan Ma, Henry Leung, and Deshi Li. (2014). Hybrid TDMA/CDMA MAC Protocol for Wireless Sensor Networks. *JOURNAL OF NETWORKS, 9 (10).*

[62] Qian Hu and Zhenzhou Tang. (2011). ATPM: An Energy-Efficient MAC Protocol withAdaptive Transmit Power Scheme for Wireless Sensor Networks. *JOURNAL OF MULTIMEDIA, 6 (2).*

[63] Radosveta Sokullu*, E. D. (2015). A Comparative Study of MAC protocols for Linear WSNs. *The 6th International Conference on Ambient Systems, Networks and Technologies (ANT 2015) (pp. 492 – 499). Elsevier.*

[64] SARIKA KHATARKAR and RACHANA KAMBLE. (2013). Wireless Sensor Network MAC Protocol: SMAC & TMAC. *Indian Journal of Computer Science and Engineering, 4 (4).*

[65] Tao Zheng, Sridhar Radhakrishnan, Venkatesh Sarangan. (2007). An adaptive energy-efficient MAC protocol for wireless sensor network. *IEEE Communication*

[66] Wei Ye, John Heidemann, Deborah Estrin. (2002). An Energy-Efficient MAC Protocol for Wireless Sensor Networks. *IEEE Communication.*

[67] T. Bheemarjuna Reddy, I. Karthigeyan, B.S. Manoj, C. Siva Ram Murthy Quality of service provisioning in ad hoc wireless networks: a survey of issues and solutions, *Ad Hoc Networks 4 (2006) 83–124, Elsevier.*

[68] Mamac: A multi-channel asynchronous mac protocol for wireless sensor networks Gholam Hossein EkbataniFard, Reza Monsefi, 2011/10/26, *International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA), 2011,91-98, IEEE*

[69] MAC Essentials for Wireless Sensor Networks Abdelmalik Bachir, Mischa Dohler, Senior Member, IEEE, Thomas Watteyne, Member, IEEE, and Kin K. Leung, Fellow, *IEEE*

[70] Mada Amarnadh, M. Venkata Dasu" Transient Analysis of Mac Protocol in Sensor Networks" ISSN 2250-3153 *International Journal of Scientific and Research Publications, Volume 2, Issue 6, June 2012*

[71] Razaque, A. and Elleithy, K.(2015) Nomenclature of Medium Access Control Protocol over *Wireless Sensor Networks, IETE Technical Review, 1, 1-2.*

[72] A.M. Firoze, L. J. (2007). PR-MAC A Priority Reservation MAC Protocol for Wireless Sensor Networks. *ICEE '07, International Conference on Electrical Engineering, 2007, Lahore, Pakistan: IEEE.*

[73] Beakcheol Jang, J. b. (n.d.). An Asynchronous schedule MAC protocol for Wireless Sensor Network. Computer Networks- *ELSEVIER 2013, 85-98.*

[74] Ben-Othman∗, B. Y. (2010). Energy efficient and QoS aware medium access control for wireless sensor networks. *Inder Science*.

[75] Jalel Ben-Othman, L. M. (2011). An Energy Efficient Priority-based QoS MAC Protocol for Wireless Sensor Networks. *IEEE Explore.*

[76] Ji, K. N. (2012). Asynchronous MAC Protocol with QoS Awareness in Wireless Sensor Network. *Globecom2012 -Adhoc and sensor networking symposium.*

[77] Kien Nguyen, T.N. (2006). A Prioritized MAC Protocol for Multihop, Event-driven Wireless Sensor Networks. *ICCE '06 First International Cence on Communications and Electronics. Hanoi, Vietnam: IEEE.*

[78] M. Yousof Naderi, M.I. (2014). RF-MAC: A Medium Access Control Protocol for Re-Chargeable Sensor Networks Powered by Wireless Energy Harvesting. *IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, 13(7), 3926-3937*.

[79] Paramasivam, A.K. (2017). PRIN: A Priority-Based Energy Efficient MAC Protocol for Wireless Sensor Networks Varying the Sample Inter-Arrival Tim. *Springer Science+Business Media New York.*

[80] Yang Liu, I.E. (2005, July 7). An energy-efficient Qos-aware media access control protocol for wireless sensor networks. *IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, 2005.*

[81] Mohammed Arifuzzaman, Mohammad Shah Alam and Mitsuji Matsumoto, *IEEE conference, 2011, CAP town, South Africa.*