Energy Efficient MAC Protocols with Adaptive Duty Cycle for Wireless Sensor Networks

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Abstract— *In Wireless Sensor Networks due to limited energy and resources it is very important to conserve energy and improve utilization of its resources by reducing latency. In this paper we focus on Medium Access Control protocols proposed to adapt towards more efficient use of energy and decreasing latency. We discuss how protocols like DMAC, T-MAC, DSMAC, AREA-MAC and adaptable CSMA/CA MAC work on sleep duration, decreasing idle listening and overhearing, and collision of packets. These protocols enhance their channel adaptation methods for varying traffic conditions, providing a tradeoff between various parameters like energy conservation, throughput, fairness and latency. Additionally we compare all these protocols based on their various assumptions and metric parameters. Finally, we discuss advantages and disadvantages of some of these protocols to provide an insight for their favorability under various environments.*

Keywords— WSN, MAC Protocol, Energy.

I. INTRODUCTION

Sensors are used in almost every area of networking and monitoring these days. With advancement in the sensor technology they have found implementation in multifarious domains of technology for providing information about their environment. Its application varies from fields like traffic management, climate control, environment monitoring, wildlife conservation to health monitoring, defense systems, robotics, space exploration and many more. The need for communication with other sensors to aggregate and fathom useful results for the above mentioned applications, is addressed – Wireless Sensor Networks (WSN)[6]. Multiple small sensors monitor various parameters of their environment and form a network of their own i.e. WSN to report any update or change. These sensors have limited capabilities and resources like battery, computation power, memory etc. Thus, it becomes of cardinal importance to use these resources very efficiently and reduce wastage. Most important of all resources is battery, which is very hard to replace particularly in a large networks, hence it is of prime importance to reduce wastage of energy and also reducing latency of sensors to improve throughput and fairness of network as a whole.

These improvements are measured under various parameters defining the quality of network like energy, latency, throughput, fairness and scalability.

Energy: Networks heavily depend on the capabilities of the large number of sensors. These sensors have limited energy capabilities as changing the batteries frequently is not a feasible solution in large WSNs. This poses as a big problem where sensors need to interact with each other, transmit, receive, compute and even store data. Hence one of the highest priorities of MAC protocol schemes is to provide an energy efficient solution and thus minimize the cost.

Latency: The delay in transfer of data among sensors and base stations is called latency. In WSNs latency play very crucial role, especially in multiple applications which require data in real time and also in applications which require data in certain time frame for a fruitful result. For this, latency has to be minimized to make the system work under required time constrains.

Throughput: The success rate of message delivery is a very important constrain in various applications. Some applications like fire monitoring completely depend on throughput for being effective as they are triggered by even a single message. Hence it is very important to deliver the message and achieve a defined success rate to make system work.

Fairness: In high traffic networks especially there arises problem of achieving fairness in receiving data from all the sensors and acquiring medium access by sensors. If a node cannot access the medium then it deprives network of fairness as the node doesn't get equal opportunity for sending data.

Scalability: MAC protocol schemes proposed the need to adapt to scalable WSN system. WSN should be able to scale by adding more sensors in the system and function normally.

MAC layer provides protocols that are necessary for nodes to transmit data by providing channel access, so that nodes may interact without any interference. The protocols suggest the methods to achieve energy efficient way to transmit data and still achieve reduced latency, high throughput, fairness and scalability depending upon the application.

This paper has the following structure:

In Section II we are describing the problem addressed by the protocols to improve MAC layer to optimize energy usage of nodes, reducing latency and hence improving throughput. In section III we mention background study of previous work on Non–adaptable MAC protocol S-MAC. In IV section we describe T-MAC, DMAC, DSMAC and AREA-MAC CSMA/CA MAC protocol scheme and how the problems are addressed then in section V Comparison we discuss how these protocols rate with each other and finally in section VI we provide the Conclusion of our study of these protocols and the possible future work.

II. PROBLEMS

Sensors in a WSN need to conserve its resources to make the network more efficient. There are many problems we have to address to achieve that. These problems give overview of the concept addressed in the MAC Protocol scheme we are going to address. These problems are:

Idle Listening: The sensor nodes in WSN are not aware of the timing or schedule of other nodes for transmitting data. So to be prepared to listen to data from other nodes at any time, it keeps its radio on all the time. Due to lack of a definite schedule in basic MAC protocol, the sensor node ends up wasting large amount of its energy in idle listening. This problem can be seen with an example as mentioned in [1] as a node exchanges data with other nodes with frequency of one message per second and while it takes around 5 millisecond (ms) to transmit it, hence in total 10 ms for sending and receiving combined. While it spends rest 990 ms of the second waiting and idle listening for messages.

Collision: In WSN when two or more than two sensor nodes try to send data at the same time across same network or using same channel, collision occurs. The colliding packets are discarded and then they are sent again after certain period of time wasting more resources of network. Due to collision the performance of the network decreases, resulting in poor fairness, throughput and energy consumption hence it is one of the major problems that are to be addressed in WSN.

Overhearing: Because the radio of the sensors is ON most of the time, the node may receive messages that are not destined for it. This results in unnecessary wastage of computational and energy resources of nodes. The node could turn its radio OFF for this period of time and save energy and decrease the redundancy and computational time.

Protocol Overhead: MAC protocols provide functionality to sensors by sending control packets along with the data/message. These control messages mostly carry various information and message handling capabilities for optimizing the MAC layer, but still these messages are excessive data that could be minimized and is considered as protocol overhead. By optimizing this protocol overhead we save packet size, computation, energy and also memory of the sensors.

III. BACKGROUND

To address the problems above we need to understand basic concept of non adaptable MAC protocols which is required to understand this paper. Sensor MAC protocol (S-MAC) is one of most popular non adaptable MAC protocol. As per [7] S-MAC is a non adaptable duty cycle MAC protocol. It makes use of four types of data packet. Synchronization packet (SYNC) was introduced in S-MAC and rest were introduced initially in MACA:

- RTS (Request To Send)
- CTS (Clear to Send)
- ACK (Acknowledgement)

As Fig. 1 explains, S-MAC divides its time period also known as the duty cycle in two parts: Active and Sleep. In sleep part it buffers all changes from its environment. When node reaches its active part it turns ON its radio and listens to all the data it is receiving. Sometime it involves idle listening or overhearing also. It will gather all the buffered messages and starts sending and receiving messages to and fro to other sensors nodes or to sink. All the sender nodes contend for acquiring the medium to send data to receiver. They do this by sending a RTS packet to the receiver. Receiver replies with CTS to the sender of first RTS it receives. All the nodes contending for sending data to that node, hear the CTS message if they are in range of radio of the sender node and get to know about the node that is cleared to send the message.

Apart from its significant improvement compared to formal MAC protocols without duty cycle, it has many problems that need to be addressed. High latency is prominent in non adaptable S-MAC because of the message arriving to sensor node during its sleep time is not acknowledged or replied to until node wakes up. Also the issue of high energy loss occurs because nodes waste energy during their wake up period of duty cycle by keeping radio ON for idle listening even when there is no data on the channel.

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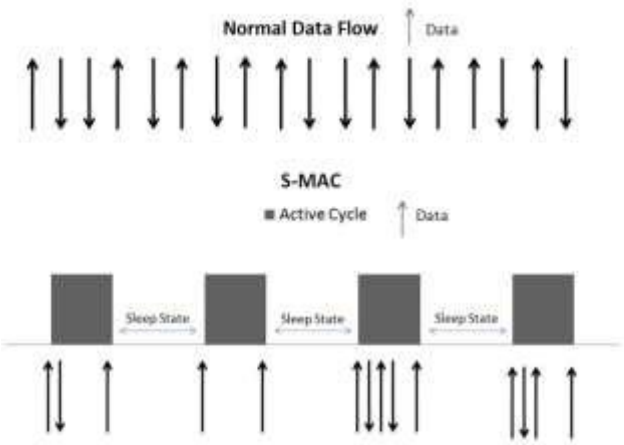

Fig.1: Normal Data Flow in MAC and S-MAC Duty Cycle Division

IV. ADAPTABLE MAC PROTOCOL

S-MAC were overcome by the new adaptable duty cycle MAC protocols. These protocols provided improved fairness, throughput, latency problem and energy efficiency by adapting their duty cycle to the load, to deadline of packet or by using low energy messages transmission etc. In the following section we will discuss basic principles of working of protocols, their environments and assumptions, their metrics, parameters, advantages and disadvantages to give a comparative study of adaptable MAC protocol:

A. T-MAC

Timeout MAC (T-MAC) is a contention based MAC protocol for WSN, where the nodes contend for data transmission to a node. It reduces energy consumption by adaptive active sleep duty cycle and hence reduce idle listening providing higher throughput and solves the problem posed in S-MAC called Early Seep Problem.

The early sleep problem arises in case where one node wants to send data to second node, second wants to send packet to third and third wants send to fourth. In such case if first node wins medium contention and starts sending data to second then forth node would remain active all the time as it is not aware of the transmission between first and second as it is out of hearing range of communicating nodes. While the third node would go to sleep, waking up at a later stage to contend again. Not being awake of both third and fourth node at same time drops the success probability of packet transmission to 50% per packet and even less for 2 or more packets. This problem is called as early sleeping problem.

As discussed in [1] when a new node joins the network, it starts listening through its radio waiting to receive any preexisting SYNC message to know the already working schedule of duty cycle among sensor nodes of WSN. If it receives any preexisting SYNC then it saves the schedule and sets its own duty cycle accordingly and transmits its schedule along with the SYNC message. In case it fails to receive any SYNC packet within a particular time period, it generates its own schedule of duty cycle and transmits its own SYNC packet.

The sensor node which wants to send data to another node initialize by sending a RTS packet to the receiver node. If receiver doesn't reply, then it will retry by sending the RTS again two times.

As mentioned above, the nodes contend for sending message. All the nodes loosing in contention go to sleep to avoid wastage of energy to contend for the medium to send again at a later point of time. In the mean time the winner node starts transmitting the data as soon as it receives CTS. At the completion of data transmission the receiver node replies with ACK message. All the sleeping node wake up after sleep period and wait for a period called Contention Interval (C) to again send RTS message for contention. C increases when the traffic is higher and vice versa. Now to implement this, the sensor node has to decide minimum time after which it will go to sleep. For this [1] suggested TA – time for minimal listening before ending the active period and going to sleep, must be long enough to hear at least the start of the CTS packet. TA is always greater then sum of time interval C, Length of RTS packet (R) and Turnaround time (T) i.e. small interval between ending of RTS packet and beginning of CTS packet.

$$TA > C + R + T \qquad (1)$$

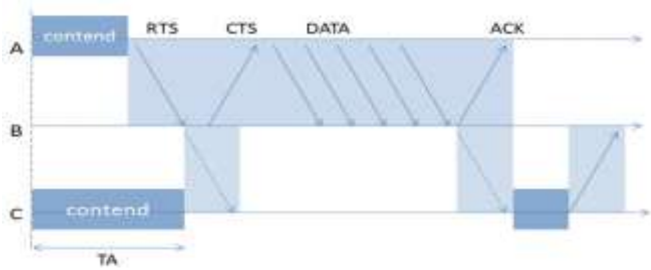

Fig. 2. T-MAC: A wants to send data to B and B to C. A wins contention, so B sends CTS to A. C overhears the CTS packet from B so it will go to sleep to wake up again in next contention period to contend.

T-MAC tries to solve the early sleep problem by using FRTS packets and Taking Priority on Full Buffers as mentioned in [1]. In FRTS packet solution, node posts a request to the future receiver node telling it to stay awake for transmission of data at a later stage in time. In another solution by [1], taking priority on full buffers, the nodes check for its buffers for sending and receiving. In case its receiving buffer is full, it prefers to send data then receiving, that means if it gets an RTS then instead of

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sending a CTS it prefers to send a RTS of its own to avoid the before mentioned problem.

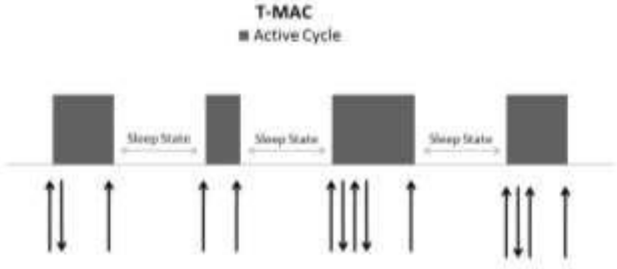

Fig.3: T-MAC with Data flow adaptable Sleep & Active states

As shown in Fig. 3, in the first Active cycle the data flow is average, so length of active cycle is also proportional. But in next Active cycle, data flow is decreased, resulting in a smaller active cycle. Similarly with the third Active cycle where data flow increases and the length of Active cycle also increases accordingly showing the adaptive changes in duty cycle of T-MAC protocol.

Advantages of T-MAC:

- adjust to data flow and hence improve energy efficiency
- Solution to early sleep problem

Disadvantage of T-MAC:

- Reduce throughput due to contention and fixed sleep cycle
- Adds Latency due to contention
- Add additional overhead for solving early sleeping problem while using FRTS

B. DMAC

According to DMAC mentioned in [2] DMAC is designed and optimized for data gathering sensor nodes tree topology in WSN. It addresses the energy, latency, throughput and fairness problems in WSN packet forwarding. As in [2] it also solves data forwarding interruption problem where the sleeping node halts the forwarding of packet. In this protocol the schedule of sensor node duty cycle depends on the depth of the node in the tree. In case there is more than one packet to send by the node below in tree topology, it proposes using More To Send (MTS) packets mechanism & Data Prediction Mechanism (DPM). DMAC is energy efficient for low load, if the load increases the latency in this protocol increases because of congestion among nodes.
DMAC works on the assumption that the nodes are fixed sensors. It assumes the node topology as a tree structure. Duty cycle of node is divided into 2 parts: sleep and active. And active part is divided into sending and receiving. One active cycle is only long enough to transmit a packet to each hop. Nodes communicate with each other by transmitting messages, but the nodes which are out of communication range are not aware of this message transmission so they go to sleep. These nodes cause interruption while data forwarding when the data needs to be communicated to any node out of the communication range of the nodes who were initially communicating. This problem is known as Data Forward Interruption.

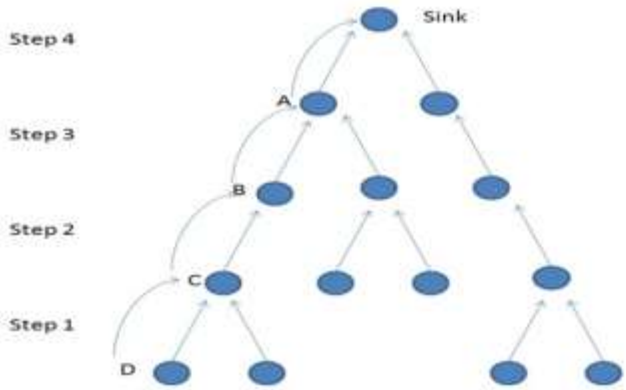

Fig. 4: Tree for data acquisition

DMAC solves this problem by Staggered Wake-up Schedule: In staggered wake up schedule the schedules of various nodes is staggered over the multihop path of data transmission. Now when the data is to be transmitted, the nodes wake up one by one to forward a packet to next hop and so on till it reaches the sink. In the Fig. 4, node D wants to send data to the sink. The route to send data is via C, B, A, i.e. D sends data to C which in turn forwards data to B which forwards data to A and A at the end sends data to Sink. According to staggered wake up schedule all the nodes in the route, i.e. C, B, A will be in active period of their duty cycle when their child needs to send data to them.
This solution also helps in reducing the sleep delay. The duty cycle is increased by only those nodes that are in the path of multihop from sender towards receiver. The receiving and sending periods for packets will be of same length µ that is enough to transmit and receive one packet. DMAC also reduces overhead by removing RTS/CTS and uses only ACK in comparison to T MAC. In ACK receiver tells the sender its willingness to be active in next slot.

In multihop chains, the nodes of WSN sometime need to send multiple data packets and to make sure its delivery [2] has used More to Flag, Data Prediction Techniques and More to Send.

More Data Flag: it is used to send more than one data packets in multihop environment. It asks nodes to increase their duty cycle after checking the more data flag. If it is active, the nodes sending more than one data packets are required to set this flag while sending and check for this

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flag while receiving. Between every sending of acknowledgements after receiving packets there is time difference of at least 3 µ.

Data Prediction: normally while sending data from multiple children to a parent, the parent node may go to sleep after the reception of data is complete from one child. While other child node of the same parent may have also data to send, and as the parent went to sleep since the other child didn't add a More Data Flag because its buffer is empty so it might have to wait till the parent wakes up. To avoid such problem parent node tries to predict the data coming from other child and hence it will sleep only for 3 µ time period, and then wake up again, to see if its other child node has any data to send. In case there is no more data to send it will go back to sleep.

More to Send Packet: in condition where two nodes A and B of different parent want to send data to their respective parents and thus, contend; node A wins then neither node B nor its parent hold any active cycle in this interval then the node B can only send packet in the next sending slot, but its parents already goes to sleep which causes this node to wait for ACK from its parent but the parent doesn't receive any packet in its receiving slot. This causes data prediction scheme to fail here. Now to avoid this condition, More to send packet is used. It is used on any of the two conditions:

1. If channel was busy because other node was using it.
2. It receives from its child and packet with MTS flag already set

It removes MTS when any of 3 conditions hold true:

1. If buffer is empty
2. All requests from children for MTS are cleared
3. It sends request MTS to its parent before and has not send a clear MTS

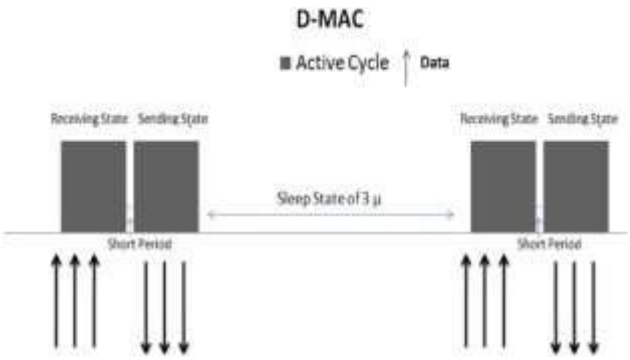

Fig. 5: DMAC Protocol

In the figure above, the node is receiving data initially. After completion of receiving it waits for a Short Period of time before starting to send data. It does so to avoid any collision or interference in packet transmission. After sending is completed it goes to sleep for a period of at least 3µ and repeats the process again.

Advantages of DMAC:

- DMAC reduces packet overhead by removing RTS/CTS and uses only ACK in comparison to T MAC
- DMAC increases the wake up time for its nodes in most of its scheme resulting in higher throughput/lower latency and higher energy efficiency.

Disadvantage of DMAC:

- DMAC is suggested for tree based topology of WSN and hence doesn't work in other topologies.
- Adds high overhead by using MTS Packet and More Data Flag.

C. DSMAC

According to [3] to manage the tradeoff between the performance and energy consumption DSMAC introduces dynamic duty cycles to adapt to variable changes in the energy consumption and latency. It alters the duty cycle and synchronizes with other nodes according to its duty cycle based on the packet load and energy consumed by nodes, and hence dynamically adapts for higher performance by the system by using less energy.

In [3] to manage according to the clock imparity SYNC messages are used by nodes. DSMAC uses SYNC in similar fashion to S-MAC. One node tries to listen to the network hoping to receive any existing wake up schedule of nodes, and adapt to the existing system. In case it does not over hear any schedule it creates it s own schedule and broadcasts the SYNC packets to other nodes to adapt to new schedule and broadcast their own SYNC packet. Every node maintains a local SYNC table to adjust its duty cycle according to load and energy consumption. Initially all sensors adopt a common service duty cycle. In comparison to S-MAC's SYNC it also contains the sender node's duty cycle in SYNC packet in DSMAC.

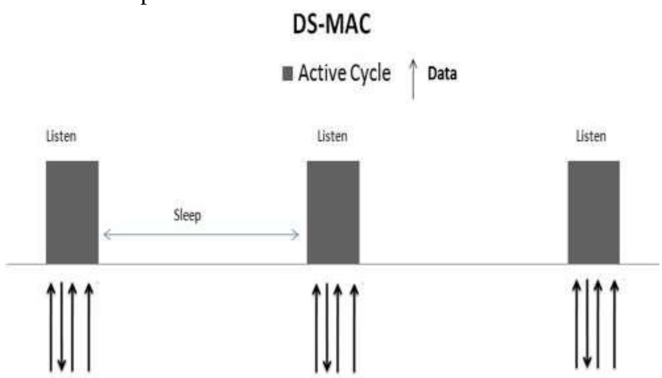

Fig.6: DSMAC for Low Load conditions

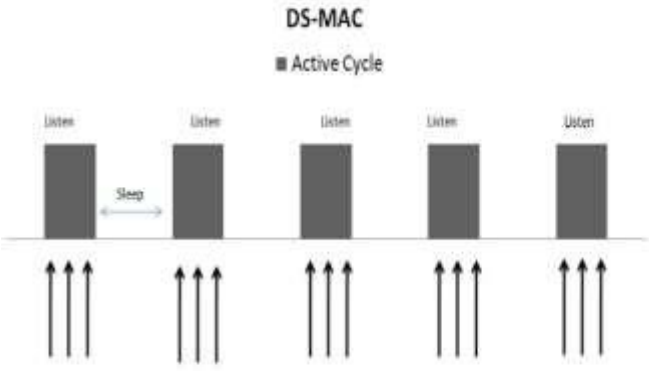

Fig.7: DSMAC for High Load conditions

All nodes adapt a common wake up schedule (Duty Cycle) at start. It uses following steps to alter its duty cycle:

1. When data packet is received, node measures the delay of packet based on the timestamp created by sender.
2. Receiving node adapts its duty cycle based on average delay, queue size and its duty cycle. It reduces its duty cycle if load is less and increases in higher load conditions.
3. It also adapts its duty cycle according to duty cycle of sender. After alteration it broadcasts its SYNC packet.

For a node if the load is low then sleep cycle would be longer as in Fig. 6 and for higher load smaller sleep cycle as in Fig 7.

Hence, by decreasing number of the active cycles of a node when the load on the node is low and increasing number of active cycles when the load is high, DSMAC manages a tradeoff between energy consumption and efficiency. Thus by following the 3 step mentioned above DSMAC adapts to varying load and provides an efficient way for increasing throughput and reducing latency.

Advantage of DSMAC:

- DSMAC is scalable as it does not affect the duty cycle of idle neighboring nodes.

Disadvantage of DSMAC:

- But it also introduces the overhead by adding timestamp to SYNC packet and delay for data packets like T-MAC.

D. AREA-MAC

AREA MAC provides a tradeoff between various parameters like latency, throughput, and energy consumption. As proposed by [4] it uses grid based wireless sensor network as a basic assumption for the AREA MAC Protocol. The nodes don't support any data aggregation or have any in-network capabilities. All nodes are fixed and know their locations regarding to their reference nodes and all nodes have a unique ID. It uses LPL (Low Power Listening) mode with short preamble messages to reduce the latency and energy consumption and improve lifetime of sensor nodes. To increase the scalability of the system the nodes are kept completely independent of the sleep wakeup schedule of other nodes in network. Sender broadcasts a LPL with short preamble message with destination ID, when nodes wake up they will check for LPL with short preamble message, if there is any LPL with short preamble message they will check the destination id provided in the message.

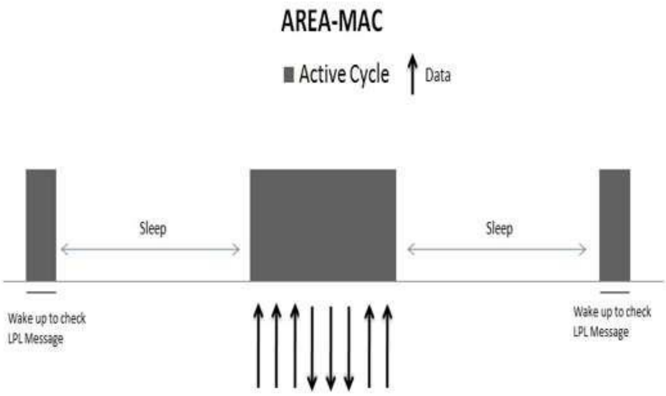

Fig.8: AREA-MAC

If the destination id matches to their ID, then an acknowledgement is sent immediately to the source node and if it doesn't then it goes back to sleep. Hence the sender node will know and stop sending any further LPL with short preamble message conserving the energy and it will start sending the data. If the node for the next hop is sleeping and sender wants to send data, it forcefully wakes up the suitable next hop neighbor, chosen on the basis of link cost metric and starts sending data and thus, provides real time support for nodes. The paper fails to provide details, how this action of forcefully waking up other nodes occur, which gives an abstract view of process.

In Fig. 8, the receiving node wakes up to check the medium for LPL with short preamble messages. It goes to sleep as no LPL with short preamble message was found for it. It wakes up after sleep cycle to check again and this time it receives LPL with short preamble message and finds it is addressed to it, so it sends back the ACK and starts transmitting data. After data transmission it goes to sleep and the cycle continues.

Advantages of AREA-MAC:

- Asynchrony: fully independent of sleep and wake up schedule of other nodes.
- Energy Efficient: Sender uses LPL approach where nodes wake up to check the data in channel and go back to sleep if there is no data for it.
- Adaptability: nodes adapt their duty cycles according to the requests received for data transmission.

Disadvantage of AREA-MAC:

- Works only in case of Grid based fixed network of sensors only, so the network cannot be dynamic in nature.
- All sensors are assumed to know location of sensors till next two hops which is a lot of overhead for sensors to store.

E. Adaptive CSMA/CA MAC

A novel adaptive CSMA/CA MAC protocols invented by Benazir and Manimaran [5], provides an insight for channel adaptation and load adaptation missing in various MAC protocols. It provides either low energy or low delay option for transmission of data for varying channel and load condition, providing low latency and high efficiency in successfully transmitting packet among nodes. It provides a metric of energy and delay in transmission of packets to decide the best message according to deadline and energy requirement and modulation level to reduce delay and energy required at time of packet transmission.

In [5] it proposes adaptive CSMA/CA MAC which uses Dynamic Modulation Scaling (DMS). In DMS we change number of bits per symbol while keeping the symbol rate constant. It uses the concept that a packet at with higher high modulation level can be sent at high energy while a packet with lower modulation level cannot. This results in a delay-energy tradeoff for each modulation level. It purports the theory that lower modulation is beneficial in some cases and in other higher may be beneficial. This allows us to develop a protocol that could sense and forward packet in either energy efficient way or delay efficient. Hence to adapt to real time networks and creates a tradeoff between the transmission delay and energy consumption during transmission.

TABLE I. COMPARISON TABLE

Protocol	Scheme Used	Timeliness	Scalibility	Throughput (in Comparison to S-MAC being Lowest)	Assumed Enviroment	Adeptive To Change	Problem Solved
T-MAC	Adaptive Duty Cycle, Overhearing, FRTS	No	No	Low	General*	Good	Early Sleeping Problem
D-MAC	Converge Cast Communication	Yes	Yes	High	Tree	Week	Data Forwarding Interruption Problem
DS-MAC	Dynamic Duty Cycle Over S-MAC	Yes (But Partially)	No	Medium	General*	Good	Latency Problem
AREA-MAC	LPL With Short Preamble Messages	Yes	Yes	High	Grid	Good	Latency Problem
CSMA/CA	Energy- Delay matrix	Yes	Yes	High	General*	Best	Best Modulation Level Selection For Energy-Delay Pair

***General – No specific topology/environment assumed**

To transmit a message successfully the probability of bit error is fixed to 10^{-6}. Thus, in the given case bit error probability is calculated and the minimum Sound to Noise Ratio (SNR) value is calculated for successful demodulation for each modulation level K. These values are used to calculate the transmission power for various K. This allows adaptive CSMA/CA MAC to cancel out those options of modulation level where transmission power is higher than the maximum transmission power of transmitter. With the help of transmission rate, transmission power per signal is calculated.

Now all the nodes in WSN who have any message to transmit in their buffer contend for medium to transmit packets and the winning node acquire the channel. The transmission power for messages is estimated for each value of K. If the transmission power is higher than the maximum transmission power of transmitter, then the corresponding values of K are discarded. It calculates the energy delay pair [E, D] for all K. For each node the Load Index (LI) is calculated which describes the message load on a sensor in contention period and by varying deadlines for packets. Load index is thus inversely proportional to period of message and directly proportional to worst-case-transmission time. The calculated load index is to generate Energy-Delay Metric (M_i) using E_i normalized transmission energy consumption and D_i normalized transmission delay.

$$LI = \sum_{i=1}^{m} \frac{WCTxi}{Pi} \quad (2)$$

$$M_i = \beta * E_i + \gamma * D_i \quad (3)$$

Where,

$$\gamma = 1/LI,\ LI \leq 1 \quad (4)$$

$$\beta = 1 - \gamma \quad (5)$$

Under current scenario of load on the channel, the minimum value of Mi represents the least energy and delay in message transmission for the modulation level i.

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Advantages of adaptive CSMA/CA:

- Dynamically adapts to load by varying modulation level.
- Energy-Delay pair provides minimum delay an efficient energy usage for message transmission.

Disadvantages of adaptive CSMA/CA:

- Overhead of calculating and maintaining Energy-Delay pair metric.

V. COMPRESSION

TMAC is better than SMAC in context of energy saving for increasing load condition (byte/node). But the problem with TMAC is in case of providing real time data, as it doesn't change sleep cycle as node doesn't receive any data during part. Still TMAC proves to be very useful for solving early sleep problem.

DMAC provides better real time data then TMAC because it uses staggered wakeup schedule and hence provide higher throughput in comparison to SMAC and TMAC as well as solve data forwarding interruption problem. DMAC work on only tree topology based WSN, so it cannot be deployed on any other topology based WSN while SMAC and TMAC do not have any specific topology requirement.

Due to the changes in the duty cycle that appear only after receiver node receives packet in condition of change in load on channel and packet delay measure by timestamp of packet, DSMAC doesn't provide real time data as efficiently as DMAC. In comparison to DMAC, DSMAC is not as much scalable because all the nodes have to adopt same duty cycle initially. But because there is no topological assumption in DSMAC, it can work on every topology of nodes in WSN.

In comparison to DSMAC, AREA MAC provides better real time data, higher throughput and is more scalable. But its application is applicable to only grid topology of WSN where all the nodes are fixed and aware of their location.

Adaptive CSMA/CA is comparatively better then AREA MAC because it considers an additional parameter for optimizing transmission, that is energy-delay metric, which provides a highly efficient energy consumption and high success ratio of data transmission by dynamically changing transmission power and rate via dynamic modulation scaling. Hence it provides highly real time data and throughput. Also because of no certain assumption about the topology of WSN, it is highly scalable.

VI. CONCLUSSION

In our day today world WSN is being used extensively and our reliance is increasing on it every day. With the growing number of fields with deployment of WSN and criticality of WSN in those domains compels us to make them more efficient. With intensive research going on in this field, MAC protocols in WSN have seen huge leaps of growth in recent times, making them more energy efficient, with low latency, high throughput, fairness and scalability. With the above discussion about MAC protocols like S-MAC, DMAC, DSMAC, AREAMAC, adaptive CSMA/CA MAC, we have provided a brief view of all these schemes, while describing their main improvements, working, and advantages. In this paper we described how S-MAC uses fixed duty cycles, T-MAC introduces adaptive duty cycles, DMAC introducing staggered wake up schedule, DSMAC using dynamic duty cycle, AREA MAC uses low power listening LPL with short permeable messages and how adaptive CSMA/CA gives concept of energy-delay metric to find best modulation level. Apart from all the advancement we have discussed in adaptive MAC protocols we believe there is room for a lot more research in this topic and many more scheme to discuss.

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