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REVIEW ARTICLE

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Investigation of Recent Energy Efficient MAC Protocols for WSN: A Review

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Abstract: Now a days the Wireless sensor networks are majorly used for environmental monitoring, tactical systems, target detection and tracking etc. While working with the wireless sensor networks, there is constraint of power source with sensor nodes, thus to make network long last we have to present and apply energy efficient methods for the nodes in wireless sensor networks. The process of energy conservation is laying vital part over the MAC layer. Thus MAC protocols are used with wireless sensor networks for communication which is resulted into the efficient utilization of energy by decreasing overhearing or idle listening, increasing sleep duration, and preventing hidden terminal problem or packets collision. Thus in this paper we carrying out recent methods for MAC protocol with an intent of energy efficiency for wireless sensor networks. We will investigate different MAC protocols along with their energy saving approaches. We will present the performance evaluation of all energy aware MAC protocols as well as their architectures.

Keywords: Wireless Sensor Networks; Medium Access Control; Protocol

I. INTRODUCTION

Various applications used in climate control, medical systems, environmental monitoring, smart spaces, target tracking etc. make use of wireless sensor networks. The Wireless sensor networks are made up of one or more battery-operated sensor devices with embedded processor, small memory and low power radio. Coverage and communication range for sensor nodes compared to other mobile devices is limited due to low power capacities of sensor nodes. These sensor networks are made up of varying number of nodes according to the requirement of covering target area. The communication between nodes in such network happens with intent of generating common task [1].

How to efficiently utilize the limited amount of energy has been the primary concern in designing MAC protocols for WSNs [2]. As there was a challenge for WSN designers to develop a system that will run for years, they used not only robust hardware and software, but also long lasting energy sources.

In shared channel, to manage the access of active node, Medium Access Control schemes are used. MAC protocol provides following functionalities:

a. ***Framing:*** Define the frame format and perform data encapsulation and de-encapsulation for communication between devices.

b. ***Medium access:*** It controls the devices to participate in communication at any time. Medium access becomes a main function of wireless MAC protocols since it broadcasts easily which cause data corruption through collisions.

c. ***Reliability:*** It ensures successful transmission between devices, mostly through acknowledgement (ACK) messages and retransmissions when necessary.

d. ***Flow control:*** From beginning to end prevent frame loss, overloaded recipient buffers.

e. ***Error control:*** In frames delivered to upper layers, to have power over the amount of errors present it uses error detection or error correction codes [3].

II. EFFICIENT MAC PROTOCOL ATTRIBUTES

In a wireless sensor network the MAC Layer protocols are supposed to perform the following tasks:

a) To create an infrastructure and establish link for data transfer.

b) To share network communication resources between sensor nodes.

The different parameters or attributes those are helpful for designing the most efficient MAC protocol for wireless sensor networks.

a. ***Energy Efficiency:*** Energy efficiency is the first attribute. Battery powered consists in the sensor nodes and it is often extremely complicated to change or recharge batteries for these sensor nodes. Sometimes it is helpful to replace the sensor node rather than recharging them [4].

b. ***Latency:*** The second is latency. Latency requirement basically depends on the application. The detected events must be reported to the sink node in real time in the sensor network applications, so that the suitable action could be taken immediately [4].

c. ***Throughput:*** With different applications the throughput requirement also varies. A few sensor network applications require sampling the information with fine temporal resolution. In such sensor applications it is better that sink node receives more data.

d. ***Fairness:*** In several sensor network applications when bandwidth is limited, it is compulsory to confirm that the sink node receives information from all sensor nodes fairly. However along with all of the above aspects the energy efficiency and throughput are the key aspects. By minimizing the energy wastage energy efficiency can be increased [4].

III. CAUSES OF ENERGY WASTAGE IN MAC

This section presents the important reasons of energy wastages in wireless sensor networks.

a. ***Collision or Corruption:*** Generally nodes may collide when neighboring nodes contend for free medium and the packet gets corrupted during transmission in loose channel. These packets need to be discarded and resent which leads to increased energy consumption.

b. ***Control Packet Overhead:*** Energy is also required for sending and receiving control packets, due to these less useful data packets can be transmitted.

c. ***Idle Listening:*** When nodes are not transmitting or receiving any data, they still remain alive and do idle listening to the network. Equal energy is consumed for Listening to receive possible traffic which is not sent, which results in wastage of energy.

d. ***Overhearing:*** Sometime nodes can pick up packets which are destined to other nodes. This also leads to unnecessary energy consumption.

For reducing the energy wastage in idle listening, protocols like SMAC, TMAC and CMAC can be used. SMAC Traditional wakeup scheduling approach which uses fixed duty cycle [4].

Duty Cycle = Listen Interval/ Frame Length

SMAC and TMAC reduce energy consumption by using coordinated scheduling, but this requires periodic synchronization. CMAC supports low latency and avoids synchronization overhead [6]. CMAC allows operation at very low duty cycles by using unsynchronized sleep scheduling .TMAC uses adaptive duty cycle and has the advantage of dynamically ending active part [1].

IV. TYPES OF MAC PROTOCOLS

The medium access control protocols can be broadly divided into two categories.

a. ***Schedule based:*** The schedule based protocols require strict time synchronization. This is based on Time Division Multiple Access (TDMA) protocol. In this mechanism the channel is divided into fixed time slots. A complete cycle of these slots is called frame. TDMA Protocols are inherently energy conserving as they reduce wastage due to Collision, Idle Listening and Overhearing.

b. ***Contention based:*** These protocols are based on Carrier Sense Multiple Access (CSMA) technique, having higher costs for message collisions, overhearing and idle listening [5]. The contention based protocols relax time synchronization requirements and can easily adjust to the topology changes by joining some new nodes. Others nodes may die after few years of deployment.

V. MAC PROTOCOLS

A. SENSOR MAC (S-MAC):

In wireless sensor network, the Sensor S-MAC protocol is a contention based MAC protocol. It is an improved version of IEEE 802.11 protocol .The sensor node periodically goes to the fixed sleep cycle for the medium access control protocol. The time frame is divided into two parts: one for a listening session and the other for a sleeping session. In SMAC, the sensor node are capable to communicate with additional nodes and send some control packets such as SYNC, RTS (Request to Send), CTS (Clear to Send) and ACK(Acknowledgement) only during listen period. By a SYNC packet exchange all nearest nodes can synchronize collectively and using RTS/CTS switch over the two nodes can communicate with each other. S-MAC proposes a low-duty-cycle operation which reduces energy consumption.

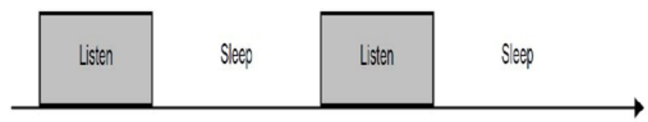

Figure 1. Periodic listen and sleep

A complete cycle of listen and sleep period is called a frame. During sleep period, the node will turn off its radio if possible. In this way, a large amount of energy consumption caused by unnecessary idle listen can be avoided especially when traffic load is light.

B. BERKELEY MAC (BMAC):

Berkeley Media Access Control (B-MAC) is another contention based MAC protocol, which is widely used in WSNs [8]. B-MAC protocol highlights the existence of “gray areas” which means some nodes exceed 90% successful reception while nearby nodes receive less than 50% of the packets. BMAC is also based on CSMA protocol having a feature of Low Power Consumption [8]. Unsynchronized duty cycling and long preambles are used in BMAC to wake up receivers.

BMAC employs an adaptive preamble sampling scheme which minimize idle listening and reduce duty cycle as shown in fig.2. B-MAC uses clear channel assessment (CCA) technique to decide if a packet is arriving when node wakes up. If no packet arrived timeout puts node back to sleep. It also uses packet backoffs for channel

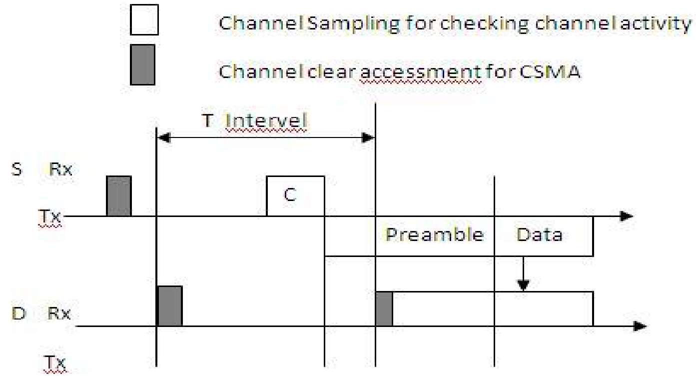

Figure 2. Preamble sampling in BMAC

C. TIMEOUT MAC (TMAC) / DYNAMIC SENSOR MAC (DSMAC):

Static sleep-listen periods of S-MAC result in high latency and lower throughput as indicated earlier. Timeout- MAC (T-MAC) [9] is proposed to enhance the poor results of S-MAC protocol under variable traffic load. In T-MAC, when no activation event has occurred listen period ends for a time threshold TA. Along with some solutions the decision for TA is presented to the early sleeping problem defined in [9]. Dynamic Sensor-MAC (DSMAC) [10] sums the dynamic duty cycle feature of S-MAC. The aim is to decrease the latency for delay-sensitive applications. Within the SYNC period, all nodes share their one-hop latency values (time between the reception of a packet into the queue and its transmission). All nodes start with the same duty cycle. Fig.3 conceptually depicts DSMAC duty cycle doubling. When a receiver node notices that average one-hop latency value is high, it decides to shorten its sleep time and announces it within SYNC period. Accordingly, after a sender node receives this sleep period decrement signal, it checks its queue for packets destined to that receiver node. If there is one, it decides to double its duty cycle when its battery level is above a specified threshold. The duty cycle is doubled so that the schedules of the neighbors will not be affected. The latency observed with DSMAC is better than the one observed with S-MAC. Moreover, it is also shown to have better average power consumption per packet [3].

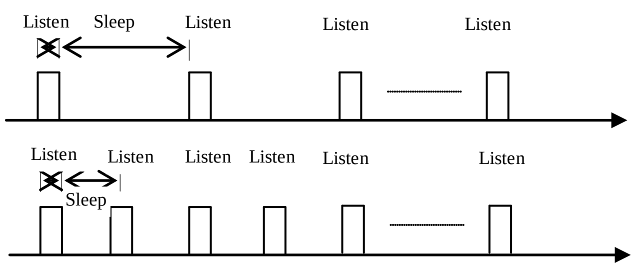

Figure 3. DSMAC duty cycle doubling

D. WISE MAC (WMAC):

The working of WiseMAC [11] when the sender starts the preamble before the receiver is expected to wake up rather than selecting a random time. For alerting the receiving node the preamble precedes each data packet. The nodes which are presents in the network sample is having the medium with a common period, but their relative schedule offsets are independent. If a node finds the medium busy after it wakes up and samples the medium, it regularly listen till it receives a data packet or the medium comes to the idle state. The size of the preamble in WiseMAC is initially set to be equal to the sampling period. Fig.4 shows preamble minimization in WiseMAC. In the Process of learning and refreshing their neighbor's the nodes sleep schedule during every data exchange as part of the Acknowledgment message. The node keeps a table of the sleep schedules of its neighbors and decides own schedule accordingly. The wake-up preamble length gets affects by the clock drifts between the source and the destination [1].

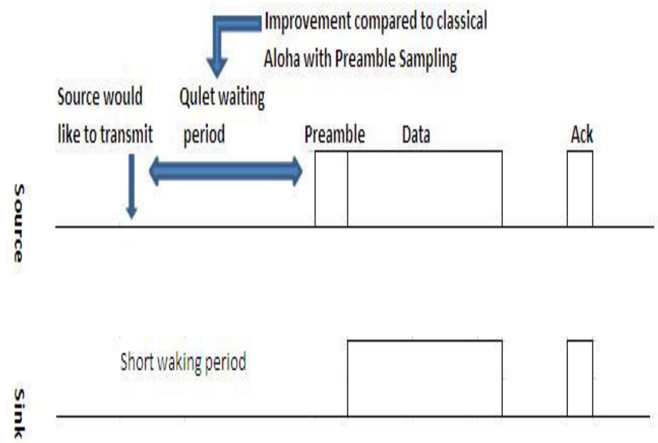

Figure 4. WiseMAC preamble minimization

E. TRAFFIC-ADAPTIVE MAC PROTOCOL (TRAMA):

TRAMA [14] is algorithm based on a TDMA it proposed to increase the utilization of classical TDMA in an energy efficient manner. It is like Node Activation Multiple Access (NAMA) [15], where a distributed election algorithm is used to select one transmitter within two-hop neighborhood for each time slot.

Random-access and Scheduled access (transmission) periods are two part of time. For establish two-hop topology information Random access period is used. It is assumed that Mac layer can calculate the transmission duration needed by the information passed by the application layer.

This transmission duration is denoted as SCHEDULE_INTERVAL. Then at time t, the node calculates the number of slots for which it will have the highest priority among two-hop neighbors within the Period [tt+ SCHEDULE_INTERVAL]. The node announces the slots which will use as well as the intended receivers for these slots with a schedule packet. A bitmap whose length is equal to the number of its neighbors is used to indicate the intended receivers by the scheduled packets. Bits correspond to one-hop neighbors ordered by their identities. Identities of the potential sender's receiver, one hop neighbors are evaluated for re-use of those slots [3].

F. CONVERGENT MAC (CMAC):

CMAC [6] is a novel MAC layer protocol; it improves energy efficiency and the latency by utilizing aggressive RTS, anycast and convergent packet forwarding mechanisms. It uses "aggressive RTS" equipped with double channel check for channel assessment as shown in Fig. 5. In CMAC there is unsynchronized sleep scheduling (or duty cycling) when there is no packet to transmit. It avoids synchronization overhead during supporting low latency. When there is no traffic, it uses zero communication CMAC allows operation at very low duty cycles. In the situation of traffic, CMAC first uses anycast for packet forwarding to wake up forwarding nodes or to quickly discover forwarder and then converges from route- suboptimal anycast with unsynchronized duty cycling to route-optimal unicast with synchronized scheduling. For flow initialization it use anycast and for flow stabilization it uses convergent Packet Forwarding.

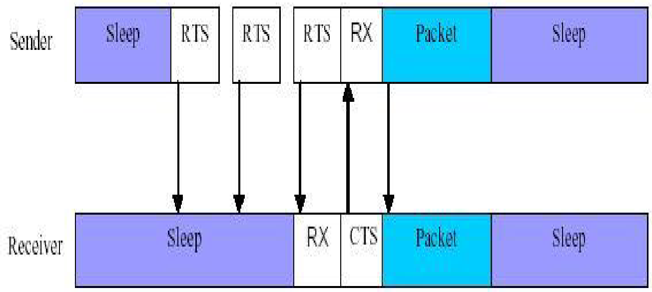

Figure 5. Aggressive RTS in Convergent MAC

The checking of the channel twice to avoid missing activities, time between the two checks should be larger than inter-RTS separation and smaller than RTS duration as shown in Fig. 6. Receiver needs to check if co-ordination that channel is busy after waking up. Time between the two checks should be larger than inter-RTS separation and should be smaller than RTS duration [1].

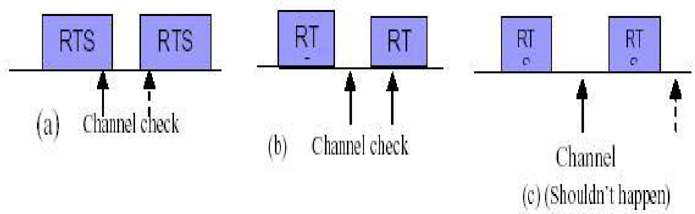

Figure 6. Double channel checking in Convergent MAC

G. H-MAC PROTOCOL:

We present a new hybrid MAC protocol- H-MAC, for sensor networks. H-MAC is based on IEEE 802.11's PSM mode and slotted aloha [6]. In H-MAC, time is divided into large frames, every frame has two parts: an active part (on time) and a sleeping part. Active part is like ATIM window in PSM mode and sleeping part is further divided into N slots, where each slot is bit bigger than data frame. Figure 1 shows the comparison between S-MAC and H-MAC time frames.

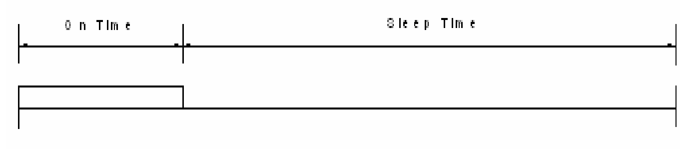

Figure 7. A time frame of S-MAC protocol

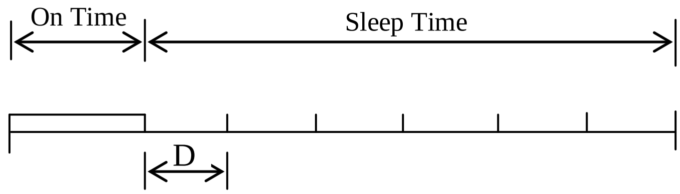

Figure 8. A time frame of H-MAC protocol

The nodes that have packets to transmit negotiate slots with the destination nodes during active time and transmit/receive the data packets in pre-negotiated slots during sleep time. If the nodes don't have to transmit or receive any data packets go to sleep during the sleep-time slots. If node A has buffered packets destined for node B, it will notify node B by sending ATIM packet. Node A includes its preferable slot(s) list in the ATIM packet. Node B, upon receiving the ATIM packet, select slot(s) based on sender's list and its own list. The receiver's list has higher priority in selecting the slot(s). After Node B selects a slot(s), it includes the slot information in the ATIM-ACK packet and sends it to node A. When node A receives the ATIM-ACK packet, it sees if it can also select the slot(s) specified in the ATIM-ACK. If node A selects the slot(s) specified in the ATIM-ACK, node A sends an ATIM-RES (ATIMReservation) packet to the node B, with node A's selected slot(s) specified in the packet. The ATIM-RES is a new type of packet used in our MAC scheme, which is not in IEEE 802.11 PSM. The ATIM-RES packet notifies the nodes in the vicinity of node A which slot(s) node A is going to use, so that the neighbouring nodes can use this information to update their list. Similarly, the ATIM-ACK packet notifies the nodes in the vicinity of node B. After the ATIM (On time) time, node A and node B will transfer the data packet(s) in selected slot(s).

VI. COMPARISON STUDY OF VARIOUS MAC PROTOCOLS

Table: 1

Protocol	**S-MAC**	**B-MAC**	**TMAC**	**WMAC**	**TRAMA**	**CMAC**	**H-MAC**
Type	CSMA	CSMA	CSMA	TDMA/CSMA	NAMA	spatial diversity	CSMA/S.Aloha
Features	Ok	Low Power Consumption, Unsynchronized Duty Cycling, Adaptive Preamble Sampling	Good	Dynamic preamble length adjustment results in better performance	distributed slot selection algorithm,	low duty-cycle, avoids synchronization overhead while supporting low latency	Good
Scheme Used	Fixed duty cycle, virtual cluster, CSMA	LPL, channel assessment software interface	Adaptive duty cycle, overhearing, FRTS	Minimized preamble sampling, schedule	TDMA	Aggressive Ack. Anycast. convergent packet forwarding	Power Saving Mechanism utilizing multiple slots dynamically
Energy Savings	Power savings over standard CSMA/CAMAC	Better power savings, latency, and throughput	Uses 20% of energy used in S-MAC.	Better than SMAC and Low Power	Utilization of classical TDMA	Consumes less energy than existing solutions	Improvement in QoS parameters using comparable amount of energy

		than S-MAC		Listening			
Advantages	Low energy consumption when traffic is low	Low overhead when network is idle, Consumes less power	Adaptive active time	Energy Consumption both at sender And receiver, and at non target receiver, increase latency at each hop.	Higher energy efficiency & throughput	high throughput, low latency & consumes less energy	Increased Multihop latency, Better throughput, Increased successful transmitted messages
Disadvantages	Sleep latency, problem with Broadcast	Overhearing, bad performance at heavy traffic. Long transmission latency	Early sleeping problem	Low power for low traffic, Do not incur overhead due to synchronization .	time is divided into random access period	Not Yet found	Energy consumption is same as S-MAC

VII. CONCLUSION AND FURTHER WORK

Most of the proposed MAC protocols for WSN networks are designed assuming that sensor nodes are stationary. This assumption is no longer valid for MSNs. Therefore designing a mobility aware MAC protocols becomes more and more important. We here discussed the new approach called MEMAC protocol - an adaptive mobility aware and energy efficient MAC protocol for MSNs. MEMAC combines the benefits of contention based and scheduled based protocols to achieve a significant amount of energy savings. MEMAC adjusts the frame length according to mobility information of the sensor nodes and the number of nodes that have data to send; this avoids wasting slots by excluding the nodes which are expected to leave or join the cluster and those nodes which have no data to transmit from the TDMA schedule, and to switch nodes to sleep mode when they are not included in the communication process. In future work we have to simulate this approach with and intention of not only efficient energy consumption but also optimized network routing performance in terms of throughput, end to end delay, packet delivery ratio and jitter.

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