A Review Paper based on Various Mac Protocols for Wireless Sensor Networks

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***Abstract*- A wireless sensor network (WSN) is formed by the nodes which observes the surroundings. Like temperature, humidity, pressure, position, vibration, sound etc. The sensor networks are used for many real-time applications to perform many different tasks example smart detecting, monitoring and control, to discover the neighbouring node, to process the data, and storage, for the routing between the nodes and base stations. In wireless sensor network the resources are limited hence, it requires a special MAC protocols. The medium access control (MAC) is an important technique that ensures the successful operation of wireless sensor networks because it controls the radio's activity of sensor nodes, which consumes node's major energy. Therefore it is important that MAC protocols must be energy efficient in the wireless sensor network as it coordinates all the nodes to share the wireless medium. In our paper we describe the categorization of MAC protocol, MAC layer related sensor network properties.**

Keywords— WSN, Medium Access Control, Radio Energy Model, Synchronous protocol, Asynchronous protocol, Frame Slotted Protocol, Multichannel Protocol.

I. INTRODUCTION

A sensor network's cover a huge number of spatially distributed, embedded devices that are networked to carefully collect the data, process the data and transfer the data to the operators and it has controlled the capabilities of processing and computing. The sensor nodes are nothing but a small computers, they work together to form a networks. In order to exchange the information with the neighbouring nodes the MAC protocol control the sensors to access a shared radio channel.

Wireless sensor networks (WSNs) comprise of one or more battery-operated sensor nodes along with the single chip embedded processor for processing unit, low power radio for wireless communication unit and small amount of processing memory, so as to reduce the energy consumption by the sensor nodes because these sensor nodes have only the battery power as the source of energy. Maximizing the battery life is a big concern for all types of energy constrained networks. Most of the research which focused on improvements in hardware technology have resulted in the design of low-power and low-cost electronic devices. This objective can be attained by maximizing the power of the battery and along creating energy-efficient networks. In spite of the progress made in this direction, the lifetime of battery Powered devices continues to be a key challenge, hence it requires additional research in energy efficient design of the platforms, protocols, and systems. In order to overcome the limitations in the hardware, Moreover the energy efficiency can be accomplished from the energy-efficient communication protocols design. In wireless networks, energy consumption is a major performance metric. If the energy consumption is lesser the functioning period of the node/network is longer. Hence, there is an increasing interest in the power saving. Conserving energy is not a problem in any particular layer of the network protocol stack; so researchers have focused on different layers in order to conserve energy more efficiently. MAC layer involves in the function and procedure which is necessary to transfer the data between two or more number of nodes in the network. The fundamental role of the MAC protocol is to avoiding the collisions occurring by the interfering nodes. The energy dissipated is more in the time period of idle listening period. Designing power efficient MAC protocol is one of the ways to extend the life time of the network. Sensor nodes consists of batteries, hence it is difficult to replace the batteries which are worn out. The activities in a sensor node which are main sources of energy consumptions are (I) sensing, (ii) computation, and (iii) radio operation. Out of these three activities the energy loss which occurs during the data transmission is maximum in radio communication [1].

Therefore, in WSN design the main aim is to maximize the node or the network lifetime. The energy consuming unit i.e. , the wireless radio for the data communication operates in four different states namely: sleep, idle, transmit, receive [2] . Although, all the active states consume the same amount of energy. Hence this problem can be tackled at software level and MAC layer is the most suitable level to tackle the energy inefficiency. The MAC layer provides a better control of the transceiver, and allows ON/OFF switching of the wireless radio.

The main aim of an energy saving mechanism of the MAC layer is how and when such switching have to be performed. In a WSN, when preserving the highest throughput, the minimum latency and maximum energy conservation. It should increase the sleep period of the node. The MAC protocol designed for WSN focuses on minimizing the energy consumption.

II. LITERATURE SURVEY

Sensor-MAC (S-MAC) [3] is a CSMA based protocol in which each and every node follows a periodic sleep and the listen time for energy efficiency. Neighbouring nodes inside a virtual clusters follow the same sleep/listen schedule and the neighbouring nodes in two different virtual clusters follow the periods of both clusters.

Dynamic Sensor MAC (DSMAC) [4] goal is to improve the latency time of S-MAC by adjusting the duty cycle of node based on the traffic and energy conditions dynamically. In DSMAC all nodes have the same duty cycle value and shared one-hop latency values in the SYNC period. When a receiver node detects the average one-hop latency value to be high, it shortens its sleep time and announces it within the SYNC period. And the sender node doubles its duty cycle after receiving this sleep period decrement signal. The latency observed in DSMAC is observed to be better than S-MAC.

Timeout MAC (T-MAC) [5] improves the energy efficiency of S-MAC by reducing the listening period of sensor node during variable traffic conditions, as the nodes closer to the sink must relay more traffic. Accordingly, a node ends its listen period when no activation event has occurred for a time threshold TA.

Berkeley Media Access Control (B-MAC) [6] a node will self-regulates the wakeup time and sleep time. The summation of awake time and sleep time period is called as check interval. The sender node sends a wake-up preamble, which is not a packet but a physical layer RF pulse, greater than the check interval which is followed by data packet. When the receiver node wakes up, then it senses the medium and if it detects the preamble, it waits for the preamble to end. If the data packet is for the node itself, it receives it otherwise goes to sleep.

Pattern MAC (PMAC) [7] is CSMA based protocol. In PMAC the wakeup and sleep time of nodes are changed dynamically depending on its own traffic pattern and that of the neighbour's.

X-MAC [8] uses the technique of strobed preamble where, the sender node sends a series of short preamble packets which contain the receiver node`s address. This allows the target node to interrupt the short preambles by sending acknowledgement, thus saving energy and reducing latency.

Low Latency MAC (LL-MAC) [9] is a TDMA based protocol which is designed with low latency as the primary goal. The data interval is divided into X divisions which in turn is divided into Y time slot subdivisions. Each node communicates to its parent in the time slot subdivision within the assigned division corresponding to the hop number it is in and the parent aggregates the data until its turn to communicate.

Wise MAC [10] is a short wakeup preamble it uses the knowledge of sampling schedule of direct neighbours of the sender node.

Funnelling MAC is a hybrid TDMA/CSMA scheme proposed to be used in the intensity region, under the control of the sink for small intensity region depths of one or two hops.

Traffic-adaptive MAC protocol (TRAMA) is a TDMA based protocol and it uses an election algorithm to select one sender within two-hop neighbourhood. In TRAMA time is divided into random-access and the scheduled-access periods. The random-access period is used to establish two-hop topology information. In scheduled-access period, each node exchange its transmission schedule to its neighbours. The election algorithm is used to select the sender and receiver for the current time slot.

Zebra MAC (Z-MAC) is a hybrid MAC protocol. It is a traffic adaptive protocol; in the low contention it behaves like CSMA to achieve high channel utilisation and low delay, and in high contention it behaves like TDMA to achieve high channel utilisation and less collision. The efficient scheduling adjustment method is used to tolerate the network topology and the data traffic variation.

Energy efficient and Quality of service aware MAC (EQ-MAC) is a Hybrid MAC protocol. It differentiates the long and short messages and it uses the priority techniques for higher priority data. It uses schedule and non-schedule techniques for data transmission for greater performance.

III. ENERGY MODEL

The energy management is the important concern in WSN. It is necessary to design an efficient energy model because in WSN there is difficulty to replace the battery, there is lack of central coordination and limited energy source in battery

The main aim in the energy constrained communication is conserving the energy and we need to concentrate on minimizing the transmission energy. There are four modes of operations Hence, the consumption of power of radio interface depends on these modes. The modes are active, sleep, idle, transient. The active mode consumes maximum power because of transmission of packets. Idle mode consumes more power because it is waiting for either transmitting or receiving the packets. Sleep mode consumes less power. Usually transition time is very less in transient mode but if any frequent transition occurs among the node then power consumption will be more. Hence, the total energy consumption represented by 'E' by a node to transmit 'K' bit can be expressed as:

$E = Pactive \times Tactive + Psleep \times Tsleep + Ptransient \times Ttransient + Pidle \times Tidle$

Pactive, Psleep, Ptransient, Pidle are the power consumption Tactive, Tsleep, Ttransient, Tidle are the duration of time.

Pactive is the summation of transmitted signal power Psig and circuit power Pckt. So 'E' can be expressed as

$E = (Psig + Pckt) \times Tactive + Psleep \times Tsleep + Ptransient \times Ttransient + Pidle \times Tidle$

The circuit power Pckt consists of the summation of Pmix, Psyn, Pfilt, PDAC, PIFA, and Pamp.
Pmix-mixer power consumption,
Psyn-frequency synthesizer power consumption,
PLNA-low noise amplifier power,
PIFA intermediate frequency amplifier power,
Pfilt at transmitter active filter power consumption,
Active filter power consumption Pfilr at receiver,
Analog to digital power PADC at receiver,
Digital to analog power consumption PDCA at transmitter and power amplifier power consumption Pamp.
The transmitter circuit power consumption:
Pckt(t) = Pmix + Psyn + Pfilt + PDAC + PIFA + Pamp
The receiver circuit power consumption:
Pckt(r) = Pmix + Psyn + Pfilr + PADC + PIFA + PLNA + Pamp

IV. MEDIUM ACCESS CONTROL (MAC) LAYER

The MAC layer operates inside the data link layer to directly interface with the physical layer in order to provide fair medium access contention and low-level reliable frame delivery. With its ability to control the radio, the MAC layer affords significant energy-saving opportunities to extend the WSN network lifetime [11][12].

A. Reasons of Energy Waste

When a receiver node receives more than one packet at the same time, these packets are called “collided packets” even if they coincide partially. Every packets which are responsible for the collision they have to be thrown out and the re-transmissions of these packets is necessary which maximizes the energy consumption. Although few packets could be recovered by a capture effect, a number of requirements have to be achieved for its success. Another reason for energy wastage is overhearing, it means that a node receives packets that are destined to other nodes. The third reason for energy wastage occurs as a result of control packet overhead. Minimum number of control packets should be used to make a data transmission. One of the major sources of energy wastage is idle listening, i.e., listening to an idle channel to receive possible traffic. The last reason for the energy wastage is over emitting, which is caused by the transmission of a message when the Destination node is not ready to receive. The reasons mentioned above can i.e. energy wastage can be overcome by designing an efficient MAC protocol.

B. Communication Patterns

Kulkarni et al. defines three types of communication patterns in wireless sensor networks: broadcast, converge cast, and local gossip. Broadcast type of communication pattern is generally used by a base station (sink) to transmit some information to all sensor nodes of the network. Broadcasted information may contain queries of sensor query- processing architectures, program updates for sensor nodes, control packets for the whole system. The broadcast type communication pattern is where, all the nodes in a network are predetermined receivers. While in the broadcast type packet the nodes which are inside the communication range of the transmitting node will be the predetermined receivers. This type of communication pattern is known as local gossip, in which a sensor transmits a data to its neighbouring nodes within a range. In some scenarios, the sensors that detect an intruder communicate with each other locally. This kind of communication pattern is called local gossip, where a sensor sends a message to its neighbouring nodes within a range. The sensors that detect the intruder, then, they need to send what they perceive to the information centre. That communication pattern is called converge cast, where a group of sensors communicate to a specific sensor. The destination node could be a cluster head, data fusion center, base station. In protocols that include clustering, cluster heads communicate with their members and thus the intended receivers may not be all neighbors of the cluster head, but just a subset of the neighbors. To serve for such scenarios, we define a fourth type of communication pattern, multicast, where a sensor sends a message to a specific subset of sensors.

C. Properties of a Well-defined MAC Protocol

To design a good MAC protocol for the wireless sensor networks, the attributes to be considered are: The first attribute is the energy efficiency. We have to define energy efficient protocols to prolong the network lifetime. Another important attribute is scalability and adaptability to changes. Changes in network size, node density and topology should be handled rapidly and effectively for a successful adaptation. Some of the reasons behind these network property changes are limited node lifetime, addition of new nodes to the network and varying interference which may alter the connectivity and hence the network topology. A well designed MAC protocol should gracefully accommodate such network changes.

V. CLASSIFICATION OF MAC PROTOCOL

MAC protocols are classified in four categories:

5.1 Asynchronous Protocols

Rather than synchronizing all the neighbouring nodes the sensor node will itself maintain its own schedule in order to process the data. By this technique the sensor node saves its cost of synchronizing and achieves a low duty cycle. A node cannot be active for long time in order to check the data of its interest it has to wake up periodically. Because of this reason a preamble sampling technique is used. In this technique information sent by the sender along with the long preamble to the desired receivers. By this the throughput is limited because of long preamble there will be over utilization of the channel. To overcome this problem i.e. in order to increase the throughput and to manage the size of preamble there are some techniques.

5.1.1 Asynchronous MAC protocols:

B-MAC (Berkeley MAC) [8] makes use of a preamble sampling to minimize the idle listening issue which is a big source of energy wastage. Also to avoid collisions CSMA with preamble sampling performs CCA (clear channel assessment) before transmitting a preamble. B-MAC performs an outlier detection to improve the quality of CCA. This special technique of preamble sampling is known as Low Power Listening (LPL). Still the hidden terminal problem has

not been solved because preamble transmission of one node may collide with the data transmission of neighbor.

To overcome this STEM (Sparse Topology and Energy Management) protocol is introduced with two radios one for data and another for wake up channel. STEM has two categories STEM-T (STEM Tone) and STEM-B (STEM Beacon). STEM-B is less energy efficient than STEM-T as channel sampling period should be longer than that of the wake-up tone in STEM-T.

These two protocols were facing the problem of collision, hidden terminal problems due to the long preamble.

ENBMAC (Enhanced MAC) is used to detect the overhearing problem by including timing data about when the data transmission begins. Based on the gap in the chunks of packets this technique is categorized as (i) Continuous preamble sampling and (ii) Strobed preamble sampling. According to that time a node will decide to stay active mode or in sleep mode.

In strobed preamble sampling protocol we can send the data immediately without any delay because ACK will be sent soon after the receiver receives the first preamble. By this the data transmission delay can be minimized and can make energy efficient protocol and also idle listening and overhearing can be avoided by the neighbouring nodes.

5.2 Synchronous Protocols

Synchronous MAC protocols. In order to set up a common sleep/active schedule in a cluster to make cluster from many nodes. If a node belongs to many cluster then it has to save many schedules which will be in conflict.

As we can see in the below figure 1 the node x belongs to two clusters namely A and B now, in this case the node x has to maintain two schedules. This will increase the additional cost for synchronization overhead. The nodes in a cluster listen to channel then the nodes will determine their next wake up time and they broadcast their own schedule. The node can even follow its neighbour's schedule in case if it receives its neighbouring cluster schedule before broadcasting its own.

A node can also be a bridge between two clusters by accepting one or more schedules. The synchronous MAC protocol concentrates on throughput and delay.

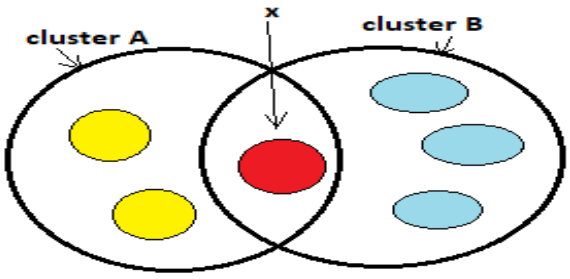

Fig. 1 Nodes in one Cluster have same schedule

TABLE I
DIFFERENT ASYNCHRONOUS MAC PROTOCOLS

Protocols	Techniques	Advantage	Disadvantage
DPS-MAC	Short strobed preamble and low power listening	Idle listening is reduced due to high energy efficiency for low traffic application	The switching time of radio is sensitive because it can affect the size of short preamble
B-MAC	Lower power listening	Frames do not require delay tolerant	Overhead is more due to long preamble
X-MAC	Minimized preamble length	Energy efficiency is high and latency operation is lesser	Neighbour transmits the packets by mistake If it gaps in packets.
Speck-MAC	Continuous preamble sampling	At receiver the energy is reduced	Because of redundancy the transmission power is wasted
PW MAC	Wakeup timer is estimated at the receiver	Because of pseudo-random schedules collisions and low delay can be avoided	Overhead due to beacons and idle listening
RC MAC	Reduced collision in the receiver initiated transmission	Even in high traffic loads throughput is high	Delay increases

TABLE II
DIFFERENT SYNCHRONOUS MAC PROTOCOLS

Protocols	Technique	Advantage	Disadvantage
T-MAC	Future request to send	Active periods are achieved optimally	Overhearing problem
S-MAC	Adaptive listening	Consumes less energy	RTS and CTS increases energy
R-MAC	Data transmission is shifted to sleep period	Overhearing is not present	Collision due to two hidden terminals
D-MAC	Staggered schedule	It is flexible to increased active slots and lesser delay	At destination contention can occur.
SCP-MAC	Adaptive duty cycle	Lower schedule maintenance	Synchronization overhead.

5.3 Multichannel MAC protocol

Recent sensor areas support multiple channels for this reason multichannel MAC protocol is an area of interest for the researchers. A single channel MAC protocol will have collision and interfaces in the channels. Hence it cannot be able to do the parallel transmission. Hence we adopt multichannel MAC protocol which helps in fast retrieval of information as a parallel transmission mechanism. In order to enhance the processing speed nodes are assigned to different

channels. Multichannel MAC protocol helps in sending data at high rate and to get high throughput.

In figure 2 below 3 concurrent slots are required to send a data which is single channel design but in the multichannel design slots of different channels are used for parallel communication.

In WSN the radio bandwidth is limited using this bandwidth only they have to support multitasking and handle the bursty traffic this is one of the big reason for using the multichannel protocols. In multichannel, the deficiency is cross channel communication it is one of the big problem. Hence, TDMA and FDMA are combined together to reduce this problem.

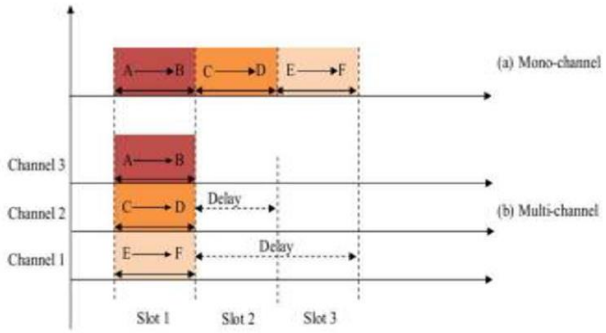

Fig 2 : Comparison between Single and Multi-channel Scheme

5.4 Frame slotted MAC protocol

TABLE III
DIFFERENT FRAME-SLOTTED MAC PROTOCOLS

Protocol	Technique	Advantage	Disadvantage
TRAMA	Adaptive assignment	Channel utilization is much compared to Z-MAC	Due to sequential node priority the spatial reuse of time slot is less
TreeMAC	Enhanced throughput at destination	Rather than individual node the fairness is ensured in terms of flow	Node requires the time to join tree because it adopts CSMA and has low channel priority
Z-MAC	Slot stealing	In low contention it produces high throughput.	To discover the abandoned slot the overhead is increased
Crankshaft	Duty cycle can be reduced by switching sending slots to receiving slots	Nodes having data can only wakeup	Collisions can occur because the time slots are assigned to the receiver

TABLE IV
MULTICHANNEL MAC PROTOCOLS

Protocol	Technique	Advantage	Disadvantage
TMCP	Metric optimization	Intra-tree interface value is reduced among trees	Actual interference intensity is not reflected by the metric
MMSN	Cross channel communication	Transmission can be done in parallel among the neighbouring nodes.	In WSN powerful radio size is not useful.
TMMAC	Cross channel communication	To enhance the flexibility dynamic ATIM window is used	Due to toggle snooping and toggle transmission node may lose energy
MC-LMAC	TDMA/FDMA to send	Channel switching is not frequently done	Channel used is lower and overhead is higher
Y-MAC	TDMA/FDMA to receive	Dynamic channel selection scheme is introduced	If two receivers opt same channel contention may occur.

VI. CONCLUSION

In this paper we have discussed various classifications of MAC protocols in four categories in WSN. The main factors considered for classification are throughput, delay, energy efficiency. In WSN MAC protocols in order to minimize the energy consumption by the node, the node must be put to the low power sleep mode. Asynchronous MAC protocol is used to establish a connection it used the mechanism to measure the best wake up time to send. The synchronous MAC protocol concentrates on throughput and delay. Frame-slotted MAC protocol overcomes the problem of collision. The multichannel MAC protocol is a challenging topic where it has to design a low overhead with dynamic channel allocation algorithm. The issue in multichannel MAC protocol is cross channel issue. Hence, we can conclude that there is no standardized technique which can classify all the protocol with a similar metric. The above mentioned techniques having the methods along with the protocols are application oriented designs.

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