Comparative Analysis of Mobility Aware Energy Efficient MAC Protocol for Wireless Sensor Networks

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Abstract: **Energy efficiency is an important requirement in designing MAC Layer in WSN. Besides that, the design must include fairness, low latency and scalability due to the dynamic topology changes in WSN environment. There is a lot more issues that must be considered when designing MAC layer such as signal loss in wireless channel, collision at the receiver's end, resource constrain (energy, bandwidth, network topology), hidden node and exposed terminal problem. The existing technique in MAC layer are contention based and schedule based. Keywords: Mobile Sensor Network, MAC protocol, Performance Analysis, Energy Efficiency, Mobility Handling, TDMA, CSMA, RWP.**

I. Introduction:

Energy efficiency is an important requirement in designing MAC Layer in WSN. Besides that, the design must include fairness, low latency and scalability due to the dynamic topology changes in WSN environment. There is a lot more issues that must be considered when designing MAC layer such as signal loss in wireless channel, collision at the receiver's end, resource constrain (energy, bandwidth, network topology), hidden node and exposed terminal problem. The existing technique in MAC layer are contention based and schedule based. Both techniques have strength and weakness when applied in WSN environment. The first technique is contention based (CSMA) which means if the node wants to access the medium or send the data it should compete with other node to get the channel [1].

Even though CSMA technique is scalable and simple, it is faced collision issue due to hidden terminal problem. Hidden terminal problem occur when two nodes that is out of range with each other intended to transmit their data to the same node in the network. Both nodes did not hear each other's signaling and assumed that the channel is idle. Then, both nodes transmit the data and cause the collision at the destination. For priority application usage, this technique is not suitable to be used to transmit the data. The collision problem in CSMA technique is encountered in schedule access (TDMA) technique. In TDMA technique, time is divided into a number of timeslots and each node in the network can access the channel in its own timeslot [3]. This technique will naturally avoid collision problem but it needs precise time synchronization and has high complexity in the scheduling process. This technique is suitable to be used for data transmission but not for exchange signaling between neighbor nodes.[2]

II. RELATED WORK:

The main job of MAC protocol is to regulate uses of medium this is done through channel access mechanism. It is way to divide resources between nodes and radio channel, by regulating use of it. Protocol tells each node when it can transmit the data and when to receive data.MAC protocol in WSN classified into three general groups: scheduled, unscheduled, hybrid protocols. In scheduled MAC protocols communication between sensors nodes are carried out in ordered way. The most common scheduling method is Time Division Multiple Access. Generally in TDMA, responsibility of base station is to coordinate the nodes of network. The channel which shows time divided into the time slots of fixed size. Each and every node of network is allocated certain no of slots where it can transmit slots are usually organized in a frame, which is repeated on regular basis. Base station specify in management frame which is in organized manner. Node follows blindly the instructions of base station. Basically the frame is organized as base station to node and node to base station slots. All the communication goes through the BS. Through connection request message it allows a node to request for connection establishment. The above mentioned frames are of different frequencies and the slots also have possibility of separate channel. IP is connectionless while TDMA is connection oriented which are used fixed size packets. TDMA organized sensor nodes to reduce collision and message retransmission. Unscheduled protocol attempt to conserve energy by allowing sensor nodes to operate independently with minimum of complexity. In addition it does not share information or maintains states. Hybrid combines the advantages of scheduled and unscheduled MAC protocol. The main advantage of hybrid protocol is its easy and rapid adaptability to traffic condition which save significant amount of energy. The basic principles of CSMA are listening before talk and contention. This is connectionless,

delivering a best services effort but no bandwidth and latency guaranty. Its main advantage is that it is TCP network protocol acquires variable condition of traffic and is robust against interference.

When we consider wired transmission then it is possible to detect collision but when we talk about wireless it leads to collision avoidance instead of detection. Firstly protocol listen to the channel and if it is found to be idle then only it send first packet to transmission queue .In case it is busy; the node waits the end of current transmission and then starts contention. In case contention timer expires and channel is still idle, For better transmission of packet node chosen shortest contention delay. The other nodes just waits for next contention because the contention is random number and done for every packet, each node is given equal chance access the channel. The most widely used MAC protocol for sensor network is SMAC protocol. It includes low duty cycle operation in multimode WSN. The node spends most of time in sleep node to reduce energy consumption. The main drawback of SMAC is probability of collision increases with increase in network size and load. The MS-MAC protocol is an improved version of SMAC protocol. MS MAC protocol handles the mobility by using simple mobility estimation algorithm which observed the mobility of neighboring node. This can be done by measuring change in received signal from neighborhoods. It can also be useful to calculate speed of mobile node. The main drawback of MSMAC protocol is it leads to high energy consumption in case of communication between mobile nodes.

MMAC is an improvement of TRAMA (Traffic Adaptive Medium Access) protocol TRAMA works on fixed time frames which make mobile node to wait long time to join the network. the problem can be solved by MMAC protocol which adjusts the frame size according to mobility in network. the drawback of MMAC protocol is its highly complex scheduling algorithm.

MEMAC is hybrid protocol which covers the drawbacks of the MMAC protocol it uses CSMA (contention slot) for short control message and TDMA (scheduled slot) for data messages. The energy efficiency in MEMAC protocol is achieved by allowing transmission to only that node which has data to be sent.

III. MEMAC PROTOCOL

In the Wireless sensor network, there may be possibility of failure of nodes because of the power drained or addition of new nodes or may be change in location of nodes due to physical movement. So to accommodate these types of dynamic changes in sensor nodes MEMAC protocol presents hybrid scheme of contention based and scheduled based scheme of previous MAC protocol having the purpose of overcome the drawbacks. For the mobility handling of sensor nodes MEMAC differs from previous SEHM protocol by acquiring frame length according to mobility conditions. The issues related to designing of MAC protocols are frame errors in mobility network, probability of collision increases in contention based MAC protocol and requires retransmission, schedule inconsistency, lack of mobility information and unable to choose mobility model. So it is necessity to cope with frame errors and adjusting frame time. To avoid collision and energy consumption it must uses mobility information and acquires schedule according to mobility conditions and it also needs proper designing of mobility model for real life setting.

Mobility Handling –

1] Mobility in sensor network responsible for packet scheduling, transmission, collision avoidance, and resolution. A mobility aware MAC protocol adjusts the frame time to reduce errors and allow nodes to make faster connections on joining or leaving the network.

2] A mobility aware MAC protocol should use the mobility information to wake up and switch off nodes accordingly in order to avoid collisions and decrease energy consumption.

3] A mobility aware MAC protocol needs to cope with synchronization, frame errors of the network and allow nodes to make faster connections on joining or leaving the network. The MAC protocol should adapt scheduling according to mobility conditions in the network and determine which and when nodes are allowed to join or leave the network to eliminate inconsistencies.

4] The mobility state S t,i of a mobile node Ni at time t (in terms of the position, velocity, and acceleration) by the following column vector:

$$S_{t,i} = [\, X_{t,i} , Y_{t,i} , X'_{t,i} , Y'_{t,i} , X''_{t,i} , Y''_{t,i} \,]$$

5] Where X t,i and Y t,i specify node's position, X't,i and Y't,i specify node's velocity, X'' t.i, Y'' t, i specify the acceleration of the mobile node Ni in the X, and Y directions, and' specifies the matrix transpose operator.

6] The mobility state S t+1,i is given as follows:

$$S_{t+1} = A_i * S_{t,i} + w_{t,i}$$

Where Ai is a 6 x 6 matrix for node Ni which captures the transition of mobility state during a discrete time step, The vector w t,i, is a 6 x 1 zero mean. [4][5]

Clustering –

1] MEMAC protocol partitions the network into clusters. Clusters are dynamically formed as all nodes in the sensor network are allowed to elect suitable cluster heads. To select cluster head time is divided into rounds with exactly one node as cluster head.

2] Initially a node decides to be CH (cluster head) with probability and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The responsibility of being a CH (cluster head) is rotated among sensor nodes to conserve energy and balance load.

3] To design cluster-heads in MEMAC protocol we are checking probability of one node that can communicate within less time with other nodes, here time is divided into rounds with exactly one node as a Cluster Head (CH) for a given round, r. Initially a node decides to be a CH with a probability p and broadcasts its decision. The random number T is chosen for CH rotation. A node becomes a CH for the current rotation round if the number is less than the following threshold:

$$T(n) = \frac{p}{1 - p(r * \bmod \frac{1}{p})} * \frac{E_{Current}}{E_{Initial}}, \quad if \quad n \in G$$

$$T(n) = 0, \quad otherwise$$

Where n is the given node, p is the initial probability of a node being elected as a CH, r is the current round number, E current is the current energy of the node, E initial is the initial energy of the node, and G is the set of nodes that have not been elected as CHs in the last l/p rounds. The round r is defined as r = k x t where, t is the frame length, and k is an integer variable greater than I. The number of cluster-heads is set to 5% of the total sensor nodes. [4][5].

Data transfer –

1] After completion of clustering phase data transfer phase begins. Data transfer in MEMAC is based on frames and the Cluster Head control the frames. The Cluster Head is responsible for controlling the channel access between sensor nodes within the cluster and collects data from them. The frames are handled during multiple phases using CSMA and TDMA scheme.

2] Each frame is composed of two slots, mini slot is used to transmit and receive control signals and consists frame synchronization, random access and receive scheduling. The normal slot is used by sensor nodes to report their data to CH (cluster head). The frame length is made dynamic to make protocol sensitive to mobility and traffic conditions.

3] Nodes that have data to send should access the channel for request/update/join phase and send their request to the CH. As well as those nodes which want to join or leave the cluster should request during that phase. Then, sensor nodes use the TDMA slots calculated and distributed by the CH to send their data during the data transfer phase to CHs. Sensor nodes that have no data to transmit go to sleep directly after the end of mini slot.[5]

IV. ENERGY CONSUMPTION ANALTYTICAL MODEL

This section describes an analytical model for estimating the energy consumption of the sensor node for the MEMAC protocol. The sampling period T can be expressed as

$$T = T_{tx} + T_{rx} + T_{idle} + T_{sleep} + T_{transition} \quad (4.1)$$

Where T_{tx} , T_{rx} , T_{idle} , T_{sleep} , $T_{transition}$ denotes the time spent on transmitting, receiving, idle listening, sleep, and radio transitions, respectively The frame time is

$$Frame=T_{SYNCrtsCTS}+T_{sleep} \quad (4.2)$$

Therefore,

$$T=T_{Frame}*F \quad (4.3)$$

Where F is number of frames during T

Where, SYNCrts= synchronous request to send, CTS = Clear to send, ACK= Acknowledge

Let P_B, E_B represent the nodes power consumption and energy consumption respectively. Where B is {tx, rx, idle, sleep, transition}. tx-transmit, rx-receive

A sensor node during awake state consumes energy by transmitting, receiving, and idle listening. During sleep state, the sensor node consumes very less energy. Moreover, it consumes energy for radio transitions or startup. Therefore, the total energy consumption of a sensor node during each T log as per trace file,

$$E = N_{tx}E_{tx} + N_{rx}E_{rx} + T_{idle}P_{idle} + T_{sleep}P_{sleep} + T_{transition}P_{transition} \quad (4.4)$$

Where N_{tx}-Total number of times the node hears, E_{tx} = Energy during transmission,

E_{rx} = Energy during receiving.

T_{idle} =Time spent on idle listening.

T_{sleep}= Time spent on sleep.

$T_{transition}$= Time spent on transition.

P_{idle} = Power during idle.

P_{sleep}= Power during sleep.

$P_{transition}$ = Power during transition.

A sensor node when transmitting a packet will send SYNCrts and DATA to the destination node, and receive CTS and ACK packets from the

destination node. Similarly, the sensor node when receiving a packet will send CTS and ACK to the destination, and receive SYNCrts and DATA from the destination.

Therefore, the energy consumption for transmitting a packet

$E_{tx} = P_{tx}(t_{SYNCrts} + t_{DATA}) + P_{rx}(t_{CTS} + t_{ACK})$ (4.5)

Where $t_{SYNCrts}$, t_{DATA} , t_{CTS} , and t_{ACK} are the times spent in sending SYNCrts, sending DATA, receiving CTS, and receiving ACK, respectively. Similarly, the energy consumption for receiving a packet,

$E_{rx} = P_{tx}(t_{CTS} + t_{ACK}) + P_{rx}(t_{SYNCrts} + t_{DATA})$ (4.6)

Therefore, the energy consumption of a sensor node in analytic method can be computed using equation (4.4) and its unknowns can be derived using (4.6), (4.5),(4.3),(4.2) and(4.1).

TABLE 4.1
PARAMETERS FOR SIMULATION ON NS-2

Parameter Name	Values
Topology	Square 100m * 100m mobile nodes are distributed randomly.
Number of sensor considered during each simulation mobility model.	1,2,3,4,5
Mobility Model	Random way point
Min. speed of mobile node	1.0m/s
Max. speed of mobile node	4.0m/s
Data size	20bytes
Duration	100sec.
Frame Length	1 Sec
Channel bandwidth	20 kbps
Data packet length	20 bytes

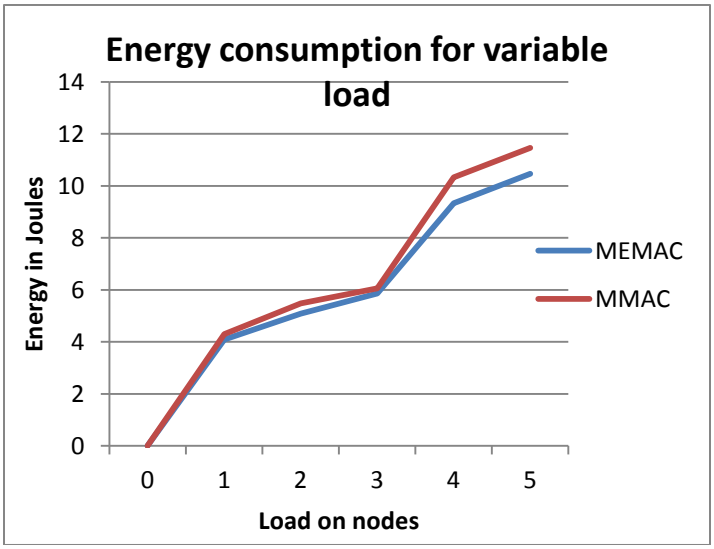
TABLE 4.2
PERFORMACNE OF MEMAC & MMAC ON NS-2 SIMULATOR

Parameter Name	**MEMAC**	**MMAC**
Power consumption for transmission	36 mw	39 mw
Power consumption for reception	14.4 mw	16.8 mw
Frame Length	1 Sec	1 Sec
Duty Cycle	15 %	15 %

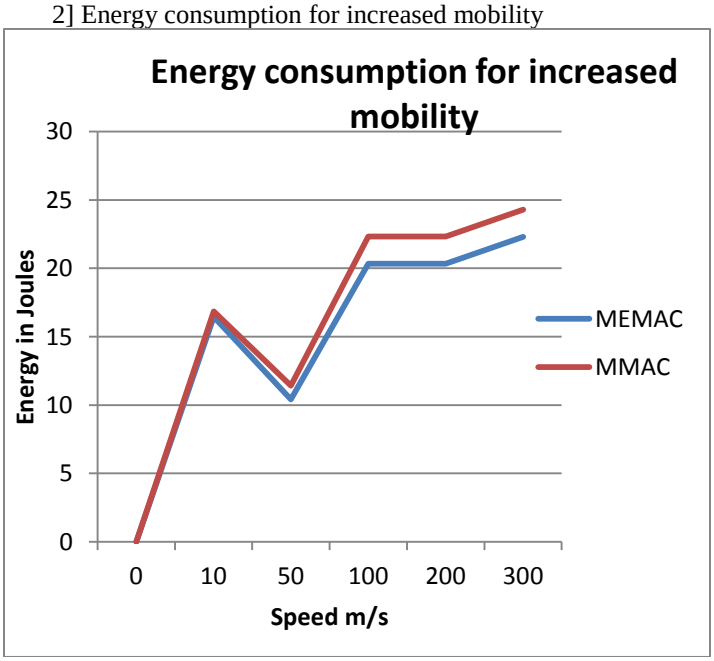
V. Result analysis:

For evaluation of MEMAC protocol we have considered 100 nodes and evaluated three parameters Energy consumption, Packet delivery ratio and packet delay. All these performance Evaluation parameters are compared with existing protocol MMAC.

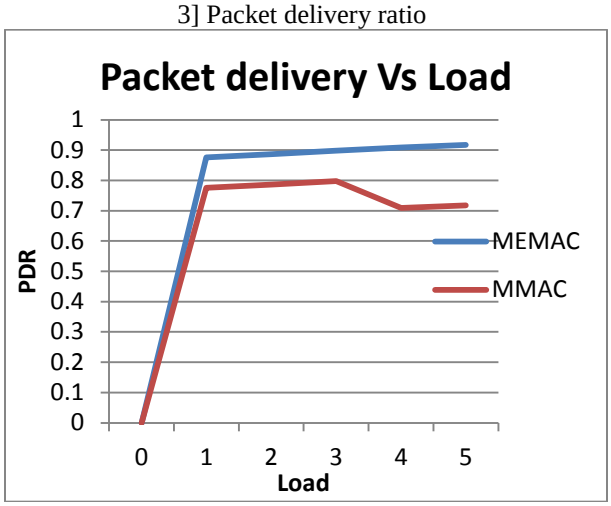
1] Energy consumption for variable traffic load on nodes.



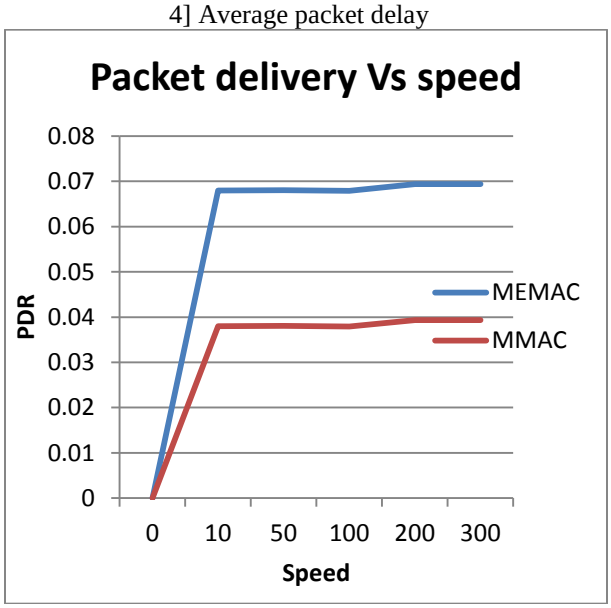
2] Energy consumption for increased mobility



3] Packet delivery ratio



4] Average packet delay



VI. Conclusion

Mobile Sensor Network has the same architecture of stationary sensor networks but only differs in the mechanism that enables devices to move in space. In this paper we present an adaptive mobility aware and energy efficient MAC protocol for wireless sensor network (briefly MEMAC) and results are compared with MMAC protocol. An effective MAC protocol for Mobile Wireless Sensor Networks must consume less power, avoid collisions, be implemented with small code size and memory requirements.

The MEMAC protocol combines channel access mechanism such as Time Division Multiple Access (TDMA) and Carrier Sense Multiple Access (CSMA). MEMAC works on contention based and scheduled based approach to achieve significant amount of energy saving. MEMAC adjusts dynamically frame size according to mobility information of sensor nodes and number of nodes that have data to send this avoids wasting slots which are expected to leave or join the network. The nodes which have no data to transmit switched to sleep mode when they are not included in the communication process. Through simulation experiments, we evaluate the performance of MEMAC protocol against MMAC protocol. Simulation results show improved results for MEMAC protocol than MMAC in terms of energy consumption, packet delivery ratio and average packet delay.

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