# *Investigation of New Energy Efficient MAC Protocol for WSN's*

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## Abstract

*Mobility together with energy efficiency in wireless sensor networks have imposed significant challenges for the medium access control (MAC) protocol design to provide reliable communication with good data rates and low energy consumption. Most of the MAC protocols proposed for wireless sensor networks assume static sensor nodes, which usually causes degradation in network performance in scenarios involving mobile sensors. In this paper, we introduce a mobility aware and energy efficient medium access protocol for mobile wireless sensor networks. This proposed protocol is based on a hybrid scheme of TDMA and CSMA that informs sensor nodes when to wakeup or when to go to sleep to save energy. Furthermore, proposed protocol dynamically adjusts the frame size to enable the protocol to effectively adapt itself to changes in mobility and traffic conditions. Through computer simulations, we evaluate the performance of this new protocol and compare it against the MMAC protocol.*

## 1. Introduction

Power management of the radio transceiver unit of a wireless device has gained significant importance with the emerging of wireless sensor networks since the radio unit is the major consumer of the sensor's energy. It has been shown that the energy consumed in transmitting one bit is several thousand times more than the energy consumed in executing one instruction. Since the radio transceiver is the major power consumer unit and the MAC protocol directly controls its operation, several MAC layer protocols have been proposed to reduce the energy consumption of the sensor's radio unit. For some examples refer to reference, which surveys a large set of MAC protocols designed specifically for WSNs [1].

MAC protocols in wireless sensor networks can be classified into three general groups: scheduled, unscheduled, and hybrid protocols. Scheduled MAC protocols attempt to organize the communication between sensor nodes in an ordered way. The most common scheduling method which organizes sensor nodes in slots is Time Division Multiple Access (TDMA), where each sensor node is assigned a time slot. Organizing sensor nodes provides the capability to reduce collisions and message retransmissions at the cost of a fine grained synchronization and state distribution. Unscheduled protocols attempt to conserve energy by allowing sensor nodes to operate independently with minimum of complexity. In addition unscheduled MAC protocols typically do not share information or maintain states. These benefits come at the cost of collisions and idle listening which may occur and cause degradation in the protocol efficiency [2] [3]. Hybrid MAC protocols combine the strengths of scheduled and unscheduled MAC protocols while avoiding their weakness to better address the special requirements of wireless sensor networks. The greatest advantage of the hybrid MAC protocols comes from its easy derive their coordinates using signal strength, time difference of arrival or angle of arrival). There are several classes of MSNs which can coarsely be structured into the following classes: i) highly mobile, which contains scenarios in which devices move at high velocities such as cars, human with cell phones, airplanes, and others; ii) mostly static which contains scenarios in which devices move at low velocities such as monitoring sensors in a shop floor with moving robots; and iii) hybrid, which contains both classes such as an airplane that has sensors installed on inside and outside [4].

There are numerous advantages of MSNs over the static WSNs. In particular, MSNs offer: i) dynamic network coverage, by reaching areas that have not been adequately sampled; ii) data routing repair, by replacing failed routing nodes and by calibrating the operation of the network; iii) data muling, by collecting and disseminating data/reading from stationary nodes out of range; iv) staged data stream processing, by conducting in-network processing of continuous and ad hoc queries; and v) user access points, by enabling connection to handheld and other mobile devices that are out of range from the communication infrastructure.

These advantages of MSNs necessitate an efficient handling of mobility in all layers of the sensor network protocol stack. The requirement to handle mobility adds another dimension to sensor network protocols, in addition to conservation of energy and computation resources. To be effective in both stationary and mobile scenarios, we need protocols that can work efficiently in terms of saving energy for sensor nodes when they are stationary, and at the same time those protocols need to provide acceptable performance level when sensors are mobile. Such protocols need to be mobility-aware and adaptive to mobile sensors' speeds [5].

Energy consumption has been considered as the single and important design key in sensor networks, hence, the most recent work on medium access control (MAC) protocol for sensor networks focused on energy efficiency, where MAC protocols play a crucial role in controlling the usage of the radio unit. The radio transceiver unit is the major power consumer unit in the sensor node. For most MAC protocols designed for WSNs, it is assumed that the sensor nodes are stationary, which causes performance degradation when these protocols are applied in mobile environments [5].

In this paper, we present an adaptive mobility aware, and energy efficient MAC protocol for wireless sensor networks [1]. This new protocol is a hybrid based MAC protocols that combines the advantages of the protocols while offsetting their shortcomings. Proposed protocol utilizes a hybrid approach of both scheduled (TDMA) and contention based (CSMA) medium access schemes. This protocol differentiates between data and control messages; long data messages are assigned scheduled TDMA slots (only those nodes, which have data to send are assigned slots), whilst short control messages are assigned random access slots. This technique limits message collisions and reduces the total energy consumed by the radio transceiver.

## 2. Formatting your paper

As this is investigation paper, in next section 3 we will present the paper contribution and related work, in section 4 we will discuss the proposed protocol for energy efficiency, in section 5 we will present the literature survey over WSN, in section 6 we will present the simulation environment that needs to be used.

## 3. Proposed Protocol

In sensor networks, nodes may fail (e.g., power drained) or new nodes may be added (e.g., additional sensors deployed), or sensor nodes may physically move from their locations, either because of the motion of the medium (e.g. water, air) or by means of a special motion hardware in the mobile sensor nodes. To accommodate these topology dynamics, our proposed protocol uses a hybrid approach of contention-based and scheduled-based schemes as in our previous MAC protocol (SEHM protocol) presented. This protocol differs from SEHM protocol in terms of mobility handling of sensor nodes. This protocol adapts the frame length according to mobility conditions by incorporating a mobility prediction model. In the following section we discuss some mobility issues. Different from MS-MAC, our proposed approach controls the channel access through scheduling the nodes in different time slots which leads to efficient usage of energy resources of the sensor's node.

## 4. Architecture of Proposed Protocol

In sensor networks, nodes may fail (e.g., power drained) or new nodes may be added (e.g., additional sensors deployed), or sensor nodes may physically move from their locations, either because of the motion of the medium (e.g. water, air) or by means of a special motion hardware in the mobile sensor nodes. To accommodate these topology dynamics, our MEMAC protocol uses a hybrid approach of contention-based and scheduled-based schemes as in our previous MAC protocol (SEHM protocol) presented. MEMAC differs from SEHM protocol in terms of mobility handling of sensor nodes.

MEMAC adapts the frame length according to mobility conditions by incorporating a mobility prediction model. In the following section we discuss some mobility issues.

### *4.1 Mobility Handling*

Mobility in sensor networks brings some challenges in designing MAC protocols, which are mainly responsible for packet scheduling, transmission, collision avoidance, and resolution. Handling mobility at MAC layer involves careful trade-off in energy efficiency, throughput, and robustness under mobility. In this section, we discuss some mobility issues relevant to the MAC protocol design [7] [8]:

• The mobility of nodes causes synchronization and frame errors in the network. A mobility aware MAC protocol needs to cope with these errors by adjusting the frame time to reduce errors and allow nodes to make faster connections on joining or leaving the network.

• In contention based MAC protocols, as mobility increase the probability of collision increases accordingly, and hence retransmissions are required which leads to high energy consumption. 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.

• In scheduled based MAC protocols, a neighbourhood inconsistency of two-hop neighbor information can occur, when mobile nodes join or leave the neighborhood. This leads to schedule inconsistencies. The MAC protocol should adapt the schedule according to mobility conditions in the network and determine which and when nodes are allowed to join or leave the neighborhood to eliminate these inconsistencies.

• Generally, mobility information needed by the MAC protocols includes node positions and the mobility information of their neighbors for better mobility detection and handling. Therefore, the mobility information has to be periodically disseminated to neighboring nodes which increases the overhead in the form of control messages in the MAC protocol. Instated of adding the mobility information into control packets of each layer, the mobility information may be made common to different layers through a common control message.

• An important limitation in designing mobility adaptive MAC protocols for sensor network is the choice of the mobility models considered in the design. It is important to choose a mobility model that applies to real life settings.

#### *4.1.1 Mobility Model*

To describe mobility in the sensor network, we use the Random Waypoint Mobility Model (RWP). It is a widely used mobility model in designing sensor networks. In RWP, nodes move from one location to another by choosing a random direction and a random speed within a specified range. The movement occurs either for a constant distance or for a constant time. A new direction and speed are chosen, once the node reaches the destination. Before any change in the speed or direction a pause time is chosen.

#### *4.1.2 Mobility Prediction*

To estimate the level or direction of node mobility, we need a mobility prediction algorithm. The accuracy of the mobility prediction model depends on the accuracy of the underlying localization mechanism. We use the first order autoregressive model that predicts the current mobility state of a node from its previous mobility state. The AR-I model defines the mobility state *St,i* of a mobile node *Ni* at time *t* (in terms of the position, velocity, and acceleration) by the following column vector:

$$S_{t,i} = [x_{t,i}, y_{t,i}, x'_{t,i}, y'_{t,i}, x''_{t,i}, y''_{t,i}]',$$

Where *x.,* and *Yt,i* specify .node's position, *X't,i* and *y't,I* specify node's velocity, *x t.is Y t,i* specify the acceleration of the mobile node *Ni* in the *x,* and*Y* directions, and' specifies the matrix transpose operator. The AR-I model for the mobility state *St+J,i* is given as follows:

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

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

Where *Ai* is a 6 x 6 matrix for node *Ni* which captures the transition of mobility state during a discrete time step, The vector *ox,* is a 6 x 1 zero mean, white Gaussian vector process with autocorrelation function *R(k) = tSk*Q,* where *tSo = 1* and *tSk = 0* when *k :;c O.* The matrix *Q*is the covariance matrix of *OJn.* In the AR-I model, the matrix *A* and the covariance matrix *Q* are completely general and can be estimated based on training data using the Yule Walker equations.

For accurate mobility prediction, a node needs to announce its mobility state at regular intervals and collect the mobility state of neighbors. MEMAC protocol includes the mobility information in the control packets to disseminate this information between nodes. A small overhead thus incurred to gain accuracy in mobility prediction.

### *4.2. Clustering and Data Transfer*

To accommodate topology dynamics and change in traffic conditions, our MEMAC uses a hybrid approach of scheduled and unscheduled protocols to address the special requirements of mobile sensor networks. Furthermore, to address scalability issues, MEMAC protocol partitions the network into clusters.

Clusters are dynamically formed as all nodes in the sensor network are allowed to content for the position of a cluster head, to finally elect suitable cluster heads. MEMAC protocol accomplishes its task through two phases; a clustering phase and a data transfer phase.

#### *4.2.1 Clustering Phase*

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. 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 cluster head is rotated among sensor nodes to conserve energy and balance the load.

The rotation is performed by getting each node to choose a random number "1'" between 0 and I. A node becomes a CH for the current rotation round if the number is less than the following threshold:

Where *n* is the given node, *p* is the priori probability of a node being elected as a CH, *r* is the current round number, *E current* is the current energy of the node, *Elnitail* 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 [3].

#### *4.2.2 Data Transfer Phase*

Upon the compilation of the clustering phase and the CHs are advertised, the data transfer phase begins. Data transfer in MEMAC is based on frames and the CHs control the frames. The CH 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 a hybrid scheme of CSMA and TDMA. Each frame is composed of two slots (see Fig. 1): mini slot and a dynamic normal slot.

The Mini-slot is used to transmit and receive control signals, and consists of three parts; *Frame Synchronization (SYNC), Random Access,* and *Receive Scheduling.* The Normal slot is used by sensor nodes to report their data to the CH. The frame length is made dynamic to make the protocol sensitive to mobility and traffic conditions (i.e. the number of time slots is increased or decreased according to the number of nodes that have data to send) [4].

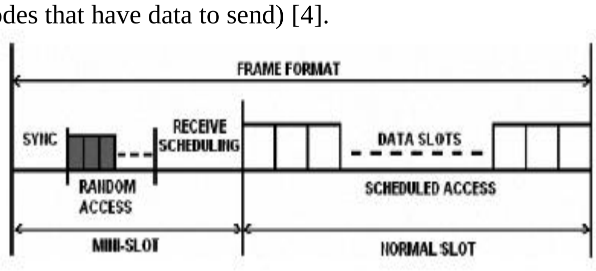


*Figure 1: Frame Format Structure*

MEMAC protocol handles the channel access through the following four phases: *Synchronization, Request/Leave/Join, Schedule Calculation and Distribution,* and *Data Transfer.*

Nodes that have data to send should content for the channel during the Request/Update/Join phase and send their requests to the CH. As well those nodes which want to join or leave to/from the cluster should send requests during this phase [1].

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 the mini-slot. More details are given below about the operation of the MEMAC protocol in different phases:

*Synchronization phase;* At the beginning of each frame, the head node broadcasts a SYNC message to all sensor nodes all sensor nodes should be in receive mode during this phase to be able to capture the SYNC message. The SYNC message contains synchronization information for the packet transmission.

*Request/Leave/Join phase;* During this phase, sensor nodes that have data to transmit content for the channel in order to acquire the access to send its request to the CH. The contention period should be long enough to enable all nodes that have data to send to pass their requests to the CH. As well, those nodes which are expected to leave or join the cluster should inform the CH by sending a leave or join message.

*Schedule Calculation and Distribution phase;* In this phase the CH calculates the schedule and broadcasts it to the other nodes within the cluster. The schedule contains those nodes which have data to send only. Nodes that want to leave or join the cluster are not considered in the current schedule.

Thus, the frame length is adjusted according to the number of request, leave, and join messages. If the number of request messages are greater than the number of join/leave messages, then the frame length is increased otherwise the frame length is reduced. The frame adjustment algorithm of the MEMAC protocol is an improved version of the mobility adaptive algorithm, the algorithm is as follow [1]:

1. For all nodes within the cluster, calculate the predicted states using the AR-l model.
2. For all nodes in the cluster, calculate the average estimated location.
3. Using the above information construct the set of joining 'J' and leaving 'L' nodes.
4. Count the request messages and construct a set of nodes which have a data to send ' R'.
5. If a node n is a member of the set of joining or leaving nodes, do not consider n in the schedule.
6. If the number of members in set 'R' are greater than the number of members in both sets of 'J' and 'L', then

increase the frame length, otherwise reduce the frame length.

7. Adjust the frame normal slot and the random access period in the frame structure according to the new frame time.

Finally, the CH broadcasts the schedule packet to all sensor nodes that contains the TDMA slots for the subsequent phase *"data transfer phase"*. In this phase all sensor nodes should be in receive mode.

*Data Transfer phase;* In this phase, sensor nodes use the TDMA slots to transmit their data to the CH or to communicate with their neighbours [1].

## 5. Work Done

The simulation work for proposed approach is carried out based on network scenarios considerations. We will present the simulation and its results analysis in our future along with routing enhancement in proposed energy efficient approach of proposed protocol. The simulations studies will be done using well know network simulation NS2 with the following performance metrics.

1) **Packet delivery ratio:** It is the calculation of the ratio of packet received by the destinations which are sent by the various sources of the CBR.

2) **Normalized routing load:** This metrics is used to calculate the number of routing packets which are transmitting with the original data packet over the network. This metrics indicates the efficiency of routing protocol in the MANET.

3) **End to end packet delay:** This metrics calculates the time between the packet origination time at the source and the packet reaching time at the destination. Here if any data packet is lost or dropped during the transmission, then it will not consider for the same. Sometimes delay occurs because of discovery of route, queuing, intermediate link failure, packet retransmissions etc are considered while calculating the delay. Such kind of metrics we have to measure against the different number of nodes, different traffic patterns and data connections.

4) **Throughput:** This metrics calculates the total number of packets delivered per second, means the total number of messages which are delivered per second.

Here we are also considering the metrics like throughput, delay, jitter for the same.

## 6. Conclusion and Future 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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*Figure 3: %Duty Cycle of X-MAC and compared LPL Protocol in dependence on Node Density, published in [5]*

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