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Mobility Tolerant TDMA Based MAC Protocol for WSN

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Abstract*—— Recent advancements in wireless communications and electronics have enabled the development of low cost sensor networks. Among the protocols of wireless Sensor Networks (WSN), Medium Access Control (MAC) protocols are given more priority as traditional MAC protocols are not suitable for Wireless communication. As many of the MAC protocols consider the sensor nodes to be stationary, and when these protocols are used in mobile environment the network performance decreases. In this paper, we introduce a new TDMA based MAC protocol which can be used in mobile wireless sensor network. This protocol uses TDMA based MAC scheme where the time will be divided into frames and then time slots. These slots are further divided into sections as channel request (CR), channel allocation (CA) and data section. We will also design an algorithm considering the energy efficiency of a wireless sensor network. Therefore the life time of the sensor nodes deployed in a wireless sensor network will be increased.

Keywords-Wireless Sensor Networks (WSN); MAC; TDMA; Communication Request; Channel Allocation; Data Section.

I. INTRODUCTION

The research area of Wireless sensor networks is an advancing technology which has opened new research issues. A sensor network is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or close to it. Some of the application areas are health, military and home. In military, for example, the rapid deployment, self organisation and fault tolerance characteristics of sensor networks make them a promising technology. In health, sensor nodes can also be deployed to monitor patients and assist disabled patients. Some other commercial applications include managing inventory, monitor product quality and monitor disaster areas.

Wireless Sensor Networks usually employ performance metrics that are different from those of more conventional data networks, emphasizing low power consumption and low cost rather than data throughput or channel efficiency. Since power is consumed every time a network device accesses the channel, the method by which the device can have a large effect on its power consumption and therefore the choice of a MAC protocol is crucial for a WSN.

The MAC protocol in a wireless multi hop self organising sensor network must achieve two goals. The first is the criterion of the network infrastructure. Since thousands of sensor nodes are densely deployed in a sensor field, the MAC scheme must establish communication links for data transfer. The second objective is to fairly and effectively share the resources between all the sensor nodes.

II. RELATED WORK

The Medium Access Control protocols can be broadly classified as following categories. They are: (1) Scheduling based and (2) Contention based. In this section some of the medium access protocols.

A. SMAC:

SMAC [3] is a contention based MAC protocol. SMAC uses three novel techniques to reduce energy consumption and support self-configuration. SMAC introduced a periodic sleep and wake up scheduling, which reduces energy consumption in listening to an idle channel. Neighboring nodes form virtual clusters to auto-synchronize on sleep schedules. SMAC also sets the radio to sleep during transmissions of other nodes. And it uses in-band signalling. Finally, SMAC applies message passing to reduce contention latency for sensor-network applications that require store-and-forward processing as data move through the network.

B. EMAC:

EMACS [2] In EMACS, time is divided into so called frames just like in TDMA but each frame is divided into timeslots and each slot contains three sections: communication request (CR), traffic control (TC), and data section. Each timeslot can be owned by only one network node. This network node decides what communication should take place in its timeslot. Other nodes can ask for data or notify the availability of data for the owner of the timeslot in the CR section. The owner of the slot transmits its schedule for its data section and broadcasts a table in the TC section, which tells to which other TC sections the node is listening. After the TC section, the transmission of the actual data packet follows. The Node goes into a standby sleep mode when at a certain time no transmissions are expected. It releases its slot and starts periodically listening to a TC section of a frame. When the node has to transmit some data (event driven sensor node), it can just fill up a CR section of another network node and agree on the data transmission, complete it and go back to sleep.

C. TRAM

In this MAC protocol time is divided into number of slots as we do in TDMA [8]. The network nodes switch in to idle mode or low power mode when they are not transmitting or receiving. A distribution election scheme is employed to determine which node to use a particular time slot. Time slots are not allotted to those nodes that do not have any data to transmit. This improves energy efficiency of the network significantly over TDMA.

D. Mobile TDMA

In [1] authors proposed TDMA-based MAC protocol for mobile sensor networks. This protocol works by first splitting a given frame into control part and a data parts. The control part is used to manage mobility, where as nodes transmit messages in data part. In data part, some slots are reserved for mobile node.

E. Mobility Models

The most widely used mobility model is random walk mobility model [4] (Brownian Movement). A slight enhancement to this model is Random Waypoint model [5]. In this model pauses are introduced between changes of direction and speed. A recent work in mobility models [6], argued that these models do not faithfully reflect reality, and developed a model based on social theory. The authors argue that, this model is well suited for MANETs. Mobility models of MANETs may not suitable for sensor networks as applications for sensor networks are tracking, monitoring, which is not the case of MANETs. However in [1] authors have introduced a novel mobility models which suit for sensor networks, viz Intra-cluster mobility and Inter-cluster mobility. In our protocol we are considering these models.

a. *Intra-cluster mobility:* When nodes are mobile, if they remain within their assigned cluster, the set of nodes within that cluster remains unchanged, though the topology may change. This is stated as intra-cluster mobility [1].
b. *Inter-cluster mobility:* When a node leaves its cluster, it will join in a new cluster due to mobility, causing the set of nodes in its original cluster to change and in new cluster also. This is stated as inter-cluster mobility [1].

In [1] authors have proven collision-freedom in intra- and inter-cluster mobility, if each node is assigned a distinct slot.

III. PROBLEM FORMULATION

In this section we discuss the problems with the present medium access protocols.

- The major problem with TDMA is the excessive delay. Each node is given a particular time slot in which it has to send its data. If the node senses some data after its slot time is over, then it has to wait till it gets a chance to transmit in its own slot in the next time frame. This results in poor channel utilization and delay. Some times because of this delay, in some energy constrained networks like WSN there is probability that the node may die before it gets its slot in the next time frame and the data is lost with the node itself. Also lots of energy is being wasted by idle listening, which brings down the network lifetime significantly.
- TRAMA solves the problem of energy efficiency by switching in to low power mode when the node is not transmitting or receiving. But the problem of delay and poor channel utilization are not resolved.
- EMACS employs the idea of dividing the time slot into sections thereby decreasing the delay and improving the channel utilization to a certain extent. But this algorithm doesn't consider the case of two nodes compete for a particular time slot whose owner doesn't have any data to transmit. There is no discussion on what priority basis the nodes compete and get the time slot.
- Also none of the above said protocols consider mobility of the network nodes. They assume that the nodes are stationary or considerably low mobility. In [1] authors proposed an algorithm for mobile nodes based on TDMA. But this has problems of delay and poor channel utilization.

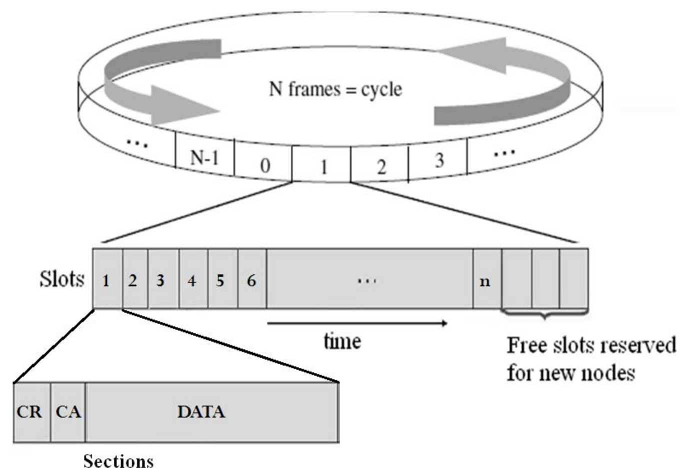

Fig. 1 Schematic of the proposed algorithm

IV. ASSUMPTIONS

- Total network is static in the setup phase.
- Cluster head have relatively more battery power and less mobility when compared to other nodes in the cluster.
- Time synchronization for all nodes is done automatically.
- Except Cluster Head all other nodes have same capabilities.

V. PROPOSED ALGORITHM

We consider the whole network to be divided in to clusters using FLOC algorithm [7]. Each cluster has its own Cluster

Head. Now as in fig.1 time is divided in to frames (*N*) and in turn divided in to time slots. Before every time frame, the Cluster Head allocates a time slot to every node (*n*) in the cluster and *x* slots are left free for the nodes that join the cluster in later part of the time frame. This *x* is considered as 10% of number of nodes in a cluster. The node which holds the current slots is known as owner node.

Whenever a new node comes and joins the cluster, the Cluster Head allocates half of the free time slots (*x/2* slots) to this node. If another comes and joins the cluster, this time it gets half of the current free slots (*x/4*). Therefore a cluster will have some empty slot at anytime in the time frame to allocate to a new node that joins the cluster. Slot allotment to new nodes joined in a cluster is explained in section *V.A*. This deals with the problem of mobility of the network nodes efficiently. But if some of the mobile nodes leave the cluster or the particular owner node doesn't have any data to send and so the channel resources are wasted. To improve the channel utilization capability we split each timeslot in to three sections. They are:

1. Communication Request (CR)
2. Channel Allocation (CA)
3. Data Section (DS).

In communication request (CR) section, owner node collects the information about the surrounding nodes. All those nodes that have data to transmit will put requests to the owner node for the grant of slot for data transmission. If the owner node doesn't have any data to transmit then it will calculate the Priority Index (PI) of each node that has put a request for grant of a time slot. Among the slot requested nodes, the node with less PI is given more priority. PI calculation is explained in section *V.B*.

In Channel Allocation (CA) section, the node decides whether to send the data and keep the channel to it or allots the channel to a cluster node which has requested for a slot and has the highest priority.

Packets are transmitted or received in this Data Section. After the communication process is over the node goes into sleep as often as possible in order to save the battery power.

A. Slot allotment:

Inter-cluster mobility causes the nodes to move from one cluster and join in new cluster. New joined node needs a slot for its further communication. Cluster Head keeps track of nodes with the cluster, nodes leaving the cluster. When a new node enters into a cluster it requests Cluster Head for a slot.

Let *r* be the number of nodes left the cluster. These r slots are left unused as their owners left the cluster. *x* be the number of slots reserved for the nodes which joins cluster because of mobility. Total number of slots available for this instant is *r+x*. For the first r nodes which joins the cluster, Cluster Head allocates r free slots which are left unused as the owner nodes left the cluster. For next the nodes which joins the cluster, Cluster Head provides half of the free time slots i.e., x/2 and so for the next incoming nodes.

B. Calculation of PI:

Priority Index is the measure that decides whether a node gets the time slot of the owner node. Higher the PI, lower the priority. It is calculated based on the following factors.

- Priority Index is inversely proportional to mobility of node. If node has higher velocity the probability that it completely transmits the packet is less, so priority of packet should be more and so the priority index should be less.

$$PI \propto \frac{1}{V} \tag{1}$$

- If battery power (BP_c) of the request node is less than threshold (BP_{th}) level, then the node cannot complete transmission of its packet, so the node should not transmit this packet. The priority of the packet should be more and hence the priority Index leads to inverse relationship.

  The PI of the packet should be inversely proportional to battery power if the battery power is less than threshold. If battery power is above the threshold level, then priority index of the packet should be more giving lower priority index values to the packets in nodes whose battery power is close to threshold value.

$$PI \propto BPc \quad \text{if } BP_c \geq BP_{th}$$

$$PI \propto \frac{1}{BPc} \quad \text{if } BP_c < BP_{th} \tag{2}$$

$$B = Sgn(BP_C - BP_{TH}) \tag{3}$$

- Depending on the difference of slot numbers between the owner nodes (s_o) and requested (s_r) node priority will be assigned.

  When the difference is positive, more difference causes more delay for transmission a packet. To reduce transmission delay, requested node (s_r) with more difference should be given more priority.

  When the difference is negative, lesser difference causes more delay for transmission a packet. To reduce delay, requested node with lesser difference should be given priority.

$$PI \propto \frac{1}{|S_o - S_r|} \quad \text{if } |S_o - S_r| \geq 0$$

$$PI \propto |S_o - S_r| \quad \text{if } |S_o - S_r| < 0 \tag{4}$$

$$D = \mathrm{sgn}(|S_o - S_r|) \tag{5}$$

Where sgn stands for signum function which is defined as

$$Sgn(y) = 1 \quad \text{if } y > 0$$
$$= 0 \quad y = 0$$
$$= -1 \quad y < 0$$

Considering all above equations PI is given as following

$$PI = B+D-v \qquad (6)$$

VI. SIMULATION RESULTS

For the comparative evaluation, we simulate the protocols extensively in MATLAB. We consider a (100x100) m^2 sensor field and the nodes (both mobile and static) are randomly deployed all over the field. Each time frame is assumed to be 1ms long and is divided into 10 equal time slots.

The parameters of the nodes used in our simulation are as shown in the TABLE I.

TABLE I
NODE PARAMETERS

Parameters	Values
Simulation area	100 X 100 m^2
Number of nodes	100
Communication radius	30m
Sensing radius	3m
Total Initial Energy	1000J
Idle cost	0.0165 J/s
Transmission Power	10 J
Reception power	2 J

For static network:

Events are generated randomly at different times in a time frame. The average delay for a message generated in a particular time frame is calculated. This average delay is plotted against the number of events occurred in a time frame. It is evident from the fig. 2 that our proposed algorithm gives lesser delay when compared to traditional TDMA.

We assume Network Lifetime to be the time taken for 10% of the total nodes in the network to fail. We then plot the network lifetime obtained by simulating the traditional TDMA and the proposed protocol. The fig. 3 clearly shows that our algorithm outperforms the TDMA by 30% approximately.

For mobile network:

In this case, 10 mobile nodes are considered to be present initially in the simulation environment. These mobile nodes (x) have some amount of mobility (M_L). A random number of mobile nodes may join the cluster, which have mobility (M_C). Channel Utilization is assumed to be the percentage of channel that is utilized in a time frame.

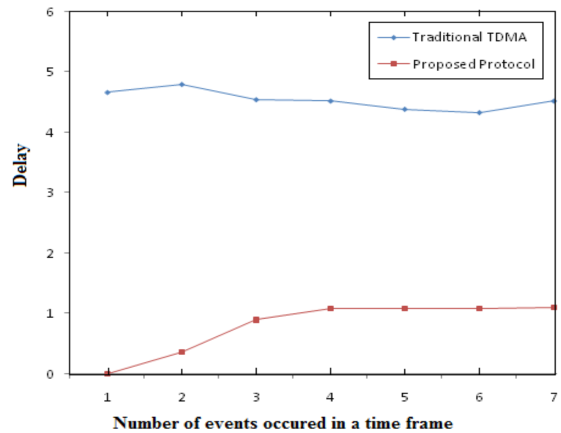

Fig. 2: Graph for Delay

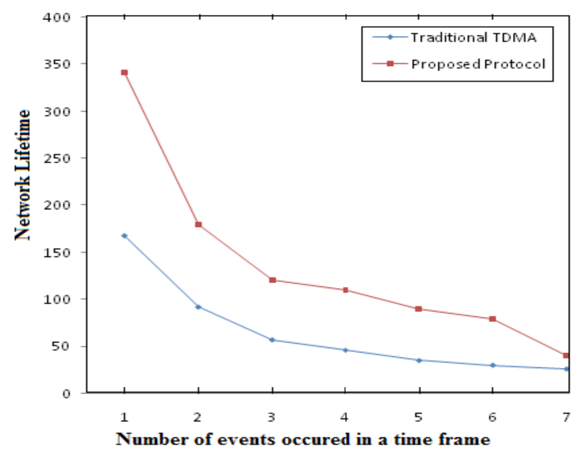

Fig. 3: Graph for Network Lifetime

When we maintain the mobility (M_L) of the nodes previously existing in the cluster to be constant and calculate the spectrum utility by varying the mobility of the incoming nodes and vice versa.

From fig. 4 and fig. 5 it is evident that our proposed protocol has good channel utilization capabilities when compared to mobile.

CONCLUSIONS

In this paper we have proposed energy efficient TDMA based MAC protocol. It has very good energy conserving properties comparing with traditional TDMA. Another interesting property of the protocol is that it has relatively very less delay when compared to traditional TDMA

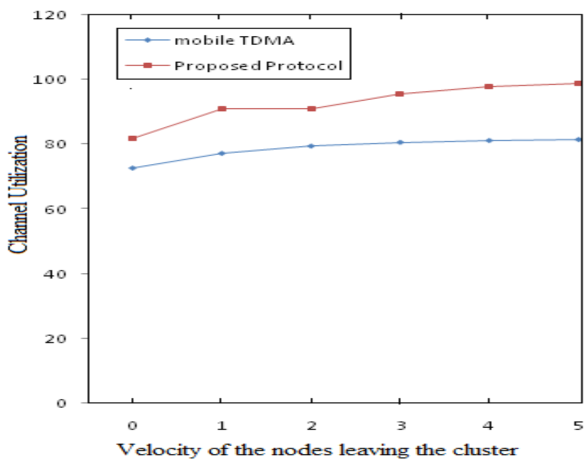

Fig. 4: Graph for Channel Utilization (I)

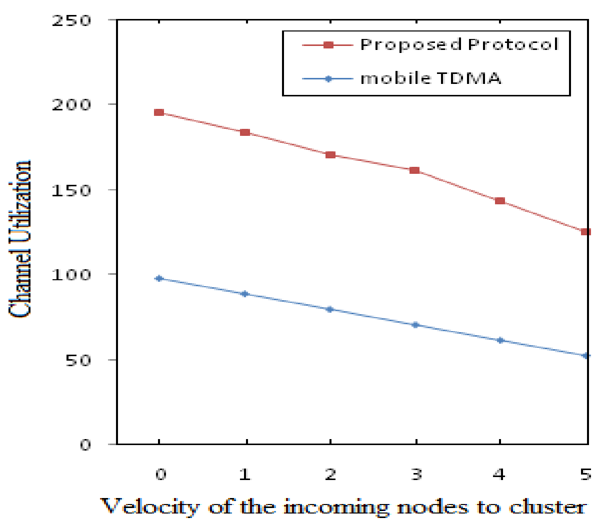

Fig. 5: Graph for Channel Utilization (II)

REFERENCES

[1] Arshad Jhumka, Sandeep Kulkarini "On the design of mobility-tolerant TDMA-based media access control (MAC) protocol for mobile sensor networks", 4th international conference on Distributed computing and internet technology, Bangalore, India, December 2007.

[2] S. Dulman, L. Hoesel, T. Nieberg, P. Havinga, "Collaborative Communication Protocols for Wireless Sensor Networks", *European Research on Middleware and Architectures for Complex and Embedded Systems Workshop*, Pisa, Italy, April 2003.

[3] W. Ye, J. Heidemann, and D. Estrin, "An energy-efficient MAC protocol for wireless sensor networks," in In Proceedings of the 21st International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM '02), New York, June 2002.

[4] Einstein, A.: "Investigations on the Theory of the Brownian Movement". Dover Publications,Mineola, NY (1956).

[5] Johnson, D.B., Maltz, D.A.: "Dynamic Source Routing in ad hoc Wireless Network",ch. 5, pp. 153–181. Kluwer Academic Publishers, Dordrecht (1996).

[6] Musolesi, M., Mascolo, C.: Designing mobility models based on social networks theory. Mobile Computing and Communications Review 1(2) (2007) .

[7] Demirbas, M., Arora, A., Mittal, V., Kulathumani, V.: A fault-local self-stabilizing clustering service for wireless ad hoc networks. IEEE Trans. Parallel Distrib. Systems 17(9), 912–922 (2006).

[8] V. Rajendran, K. Obraczka, and J.J. Garcia-Luna-Aceves, "Energy-Efficient, Collision-Free Medium Access Control for Wireless Sensor Networks", *The First ACM Conference on Embedde Networked Sensor Systems (SenSys 2003),* Los Angeles CA, Nov. 2003.