Hybrid MAC Protocol for Wireless Sensor Networks with Emergency Response

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***Abstract* - Emergency Response MAC (ER-MAC) is a hybrid MAC protocol that has been designed for networks which is wireless in nature to monitor the emergency situations. The mode switching during emergency situations is done to handle heavy traffic by changing the topology (to reduce packet loss), marking the packets with various priorities and guaranteeing fairness. The ER-MAC protocol combines both Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) and Time Division Multiple Access (TDMA) for providing flexibility for acclimatizing with traffic and topology changes. As TDMA is used, nodes wake up only at the beginning of their allotted slots. When an emergency situation occurs then the nodes change their MAC behavior allowing contention in TDMA slots. Because of contention, high data delivery ratio and lesser delay are achieved. The ER-MAC protocol is has a unique property which gives precedence to the nodes with emergency data. The ER-MAC protocol will be simulated using NS2. The simulation results show that ER-MAC protocol is scalable and performs better than the existing protocol, the Z-MAC (Zebra-MAC) protocol.**

***IndexTerms* - Wireless sensor networks, Media access control (MAC), Emergency Response, Time Division Multiple Access (TDMA), and Carrier Sense Multiple Access (CSMA).**

I. INTRODUCTION

A collection of sensor nodes spread across a wide area forms the Wireless Sensor Network. WSNs are applied for various applications including monitoring of conditions in the surroundings. In this course of action, the information that is to be transferred from various nodes will be passed through the intermediate nodes till it reaches the destination. The sensors are very small devices used for real time applications sometimes in harsh or hostile environments, replacing and recharging of the sensor nodes is very difficult. Hence the energy within each of the sensor nodes must be utilized very carefully and in the course energy must be conserved. This helps in protruding the network's age to a certain extent. The MAC has the functionality to allocate media to the competing nodes. MAC protocol must also be designed and selected in such a way that it manages and adjusts to the changes in traffic and topology. WSN associated with the MAC layer is most widely used for energy preservation as the layer comprises every job relative to distribution, communication, channel access management, collision avoidance and handling clustering and different tasks. ER-MAC protocol summarizes the characters mainly which is relative to MAC layer protocols, and combines some mixed extensive hybrid MAC protocols designed for WSNs keeping in mind the protocol's advantages and disadvantages.

Emergency Response (ER) MAC protocol is introduced as hybrid MAC protocol to examine and handle emergency situations in emergency response wireless sensor networks. ER-MAC uses CSMA/CA and TDMA approaches so that flexibility is provided when the traffic or topology changes. Normally, nodes stay in power saving sleep mode and during their scheduled slots, they wake up and check for any function to perform and does the work. During emergency situations only the nodes that take part in emergency response vary their MAC behavior so that emergency data is transferred as soon as possible. Use of hybrid MAC protocol provides high data delivery ratio and low latency. The nodes will have synchronized and loose slot structure that is, any changes, additions or deletions in the network are done locally. Hence the nodes can attach themselves into the network or resign from the network easily. The protocol prioritizes the packets and puts them in different queues so that the emergency data reaches the destination as soon as possible. Fairness over the packet sources is guaranteed so that the designated sink nodes receive the complete information about the situation from all the nodes involved.

II. RELATED WORK

The MAC can be contention based or schedule based or a hybrid of both of them. X-MAC [4], MAX-MAC [5], EB-MAC [8], Funneling MAC [7] are some of the protocol that were proposed earlier. All these protocols conserve energy and will also adapt to topology changes but have some or the other disadvantages. They may not prioritize the packets or will not provide complete fairness to the network.

Z-MAC [6] protocol was proposed as a hybrid MAC protocol to handle wireless sensor networks. This Protocol Is Designed To Overcome The Problems Of Collisions, Overhearing And Idle Listening. This Protocol Adjusts To Traffic and Topology Variations

and Assures Fairness Support to the entire network. Like CSMA, Z-Mac Achieves Greater Channel Utilizations and less delay during low contention and like TDMA, Z-MAC achieves high channel utilizations and low latency under high contention and lessens collision within two hop neighbours at lesser cost. Fairness is ensured so that sink receives complete information from all nodes. Main objective of Z-MAC protocol will be to increase throughput. The protocol's performance is robust. The implementation of the Z-MAC protocol is done using the Tinyos.

Knowledge of the topology and loosely synchronized clocks is used by the Z-MAC protocol as hints. These hints improve the performance of the MAC under high contention. When these hints are not trustable and when the condition is under the low contention, Z-MAC acts as CSMA. Z-Mac will be helpful for the applications in which the desired data rates and two-hop contention would be from mediocre to higher level. Z-MAC's design strategy is that initial overhead that will be high is amortized for long time of network operation, and subsequently replaced with improvised throughput and efficient energy. Though Z-MAC overcomes the problem of collision, overhearing and idle listening, it does not prioritize the packets into high and low priority packets. The network cannot identify which packets have emergency data that need to be sent first. As a result, some times the high priority packets may be delayed and also can be lost. The sink may not receive the complete information also.

III. PROPOSED SYSTEM

As the proposed system, ER-MAC protocol is designed. This protocol is hybrid MAC protocol (containing features of CSMA/CA and TDMA approaches) designed to take care of emergency situations. This hybrid approach gives ability to acclimatize to variations of traffic and topology in the network. In this protocol, to schedule collision free slots, TDMA approach is used. As a result of this, the nodes remain in the power maintainable sleep mode and wake up only at the beginning of their scheduled slots.

The main functions performed by the ER-MAC protocol are:

a) Establish data gathering tree with root being the sink and also get back and follow neighborhood connectivity information.
b) Establish node schedules.
c) Make sure of local time synchronization to manage the clock drifts.
d) Different priority packets are managed by establishing two different priority queues.
e) Cope with the large volumes of emergency traffic, MAC behavior needs to be changed to respond to the emergency events.
f) During any variations in the network topology, network should be managed.

To avoid collision, ER-MAC first contacts the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) which includes random back off mechanism. Every transmission abides by series of Request-to-Send (RTS)/Clear-to-Send (CTS)/DATA/ACK. For exclusive communication among the nodes, initially, data gathering tree and TDMA schedules will be formed. ER-MAC integrated with routing functions is renowned as the most efficient within network protocol design for WSNs though this integration is less flexible. Because of the MAC protocol and routing protocol integration, energy efficiency is improved by eliminating the unnecessary protocol overhead. Also, resource management is improved with sharing resources among both layers. In data gathering tree, all nodes will have a parent child relationship. The entire node will have children node leaving the non leaf nodes and all the nodes will have a parent node leaving sink as sink node is root node. The nodes pass their data and their neighbor's data for respective parent node because of the usage of TDMA schedules. Because of the TDMA schedules the nodes can transmit in collision free slots. In the ER-MAC protocol, there will be slots for broadcasting messages between parent and children and also slots for allowing entry of new nodes into the network. For a new node there will be a contention free slot. This will mostly be the last frame. This slot is besides the contention-free slots.

To handle various packets types like packets with greater and lesser priority data, ER-MAC uses two queues. If there is no data to send in most prioritized queue then only chance will be given to the data in the low priority queue. Data packets will be ordered depending upon slack within a queue. Slack is defined as the time that is left over until the deadline of the packet expires. This timestamp will be decided by a particular WSN application for specifying required limit on end-to-end delay. The deadline would be initialized by source node. If the queue becomes full with data packets then that packet is dropped which has the shortest slack as anyway it would expire before its deadline. During the normal mode, the nodes will be in the power saving sleep mode until its scheduled time slot comes up. However, during the emergency situations the nodes affected by the hazard changes the MAC behavior. In the emergency mode, if a node's one hop neighbor has emergency data to send then that node allows its neighbor to compete for the slot. But, check has to be made to see that the schedule is not conflicting with the schedule of the two hop neighbor. This is possible only because of the usage of the ER-MAC protocol. The owner of time slot will have high priority to send its high priority data first and also to compete for the slot before the non owner of time slot could compete for the schedule. During emergency, the nodes that have changed their MAC behavior to hazardous mode would wake up in beginning of every TDMA slot for any available reception. Further, addition and deletion of node, packet overheads and network lifetime is examined. ER-MAC avoids the problem of collision, overhearing and idle listening and uses local time synchronization so that the nodes can be synchronized with each other to avoid clock drifts.

IV. SIMULATION RESULTS

The simulation is done with a network containing finite set of nodes with a static sink node. The proposed protocol is implemented with Network Simulator 2. The proposed protocol is compared with the existing protocol and compared across some metrics. During simulation, if there is an emergency situation, a node nearby comes to know and change its MAC and transfers the information to its related nodes. Thus all the nodes that are required will be involved in the situation with varied MAC behavior. Due to the hazardous situation, the data transfer will be very fast thus increasing the traffic load on the network. The proposed protocol handles this situation by assuring reliability of data delivery and also with minimal delay. Also care is taken that when there is no emergency condition, the network will be conserving the energy.

The graph shown in fig. 1 shows the packet delivery ratio of the nodes. Through the graph it can be known that proposed protocol provides better ratio then the existing one. Similarly fig 2. shows that the proposed protocol does not drop much packets when compared with the previous protocol. Fig 3. shows less delay during the data transmission and fig 4. shows good throughput by the proposed protocol.

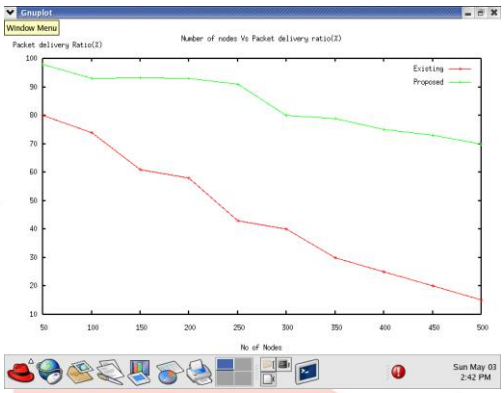

Fig 1: Packet delivery ratio of each node

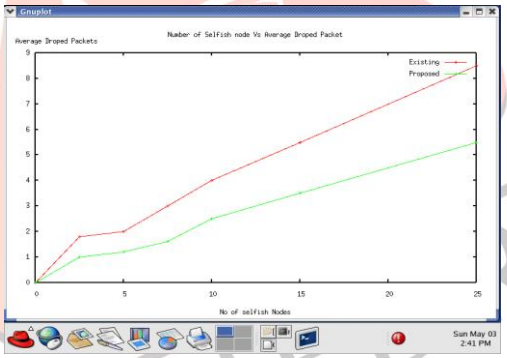

Fig 2: Average packet dropped by selfish nodes

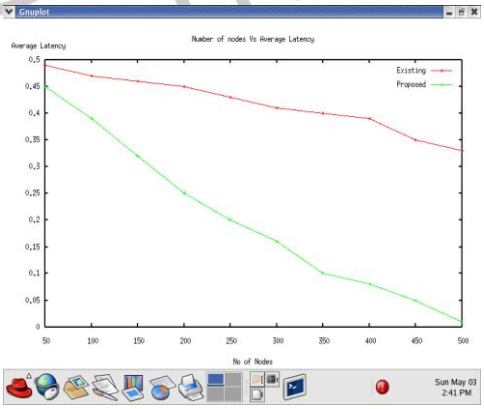

Fig 3: Average latency

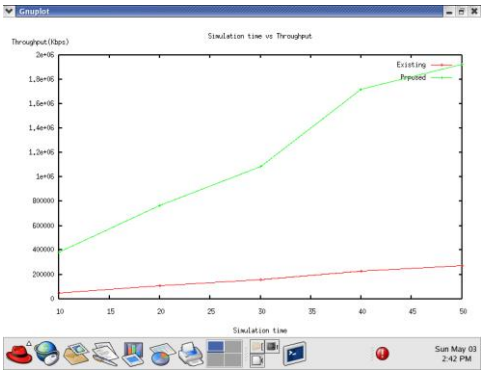

Fig 4: Throughput compared with simulation time

V. Conclusion and Future Enhancement

From the implementations it can be concluded that ER-MAC protocol is a good protocol that can be implemented to the wireless sensor networks that are applied to check on the emergency data. This protocol helps transfer the emergency data to the base station as early as possible with the data being delivered well. The delay in transfer is also cut down. Nodes carrying emergency data are given importance. Fairness is assured by the ER-MAC protocol so that the sink will have the entire information of the network. Simulations done in Network Simulator-2 tool depicts the scalability of the ER-MAC protocol and provides good ratio for the data delivery with limited delay during emergency situation. The evaluations show that ER-MAC protocol outperforms the Z-MAC protocol. As a future enhancement dynamic link estimation can be incorporated in the ER-MAC protocol. Network security could also be provided to the network so that no intruder sends bogus data as emergency data and puts on heavy traffic.

VI. References

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