Medium Access Control for Wireless Sensor Networks

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***Abstract*—Medium access control for wireless sensor networks has been a very active research area for the past couple of years. The most of the literature in the medium access for the sensor network focuses on the energy efficiency. The proposed MAC protocol solves the energy inefficiency caused by idle listening, control packet overhead and overhearing taking nodes latency into consideration based on the network traffic. Simulation experiments have been performed to demonstrate the effectiveness of the proposed approach. This protocol has been simulated in Network Simulator ns-2.**

I. Introduction

Wireless Sensor Networking has emerged as one of the dominant technology trends of this decade (2000-2010) that has potential usage in defense and scientific applications. These sensor networks can be used for target tracking, intrusion detection, wildlife habitat monitoring, climate control and disaster management. Such network will consist of large number of distributed nodes that organize themselves into a multi-hop wireless network. Each node consists of a sensor, embedded processor, moderate amount of memory and transmitter/receiver circuitry. These nodes are normally battery operated and coordinate to perform a common task.

Like in all shared medium networks, medium access control (MAC) is an important technique that enables the successful operation of the network. One fundamental task of the MAC protocol is to avoid collisions from interfering nodes.

To design a good MAC protocol for the wireless sensor networks, we have considered the following attributes. The first is the energy efficiency. As stated above, sensor nodes are likely to be battery powered, and it is often very difficult to change or recharge batteries for these nodes. In fact, some day we expect some nodes to be cheap enough that they are discarded rather than recharged.

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Prolonging network lifetime for these nodes is a critical issue. Another important attribute is scalability and adaptivity to changes in network size, node density and topology. Some nodes may die over time, some new nodes may join later, some nodes may move to different locations. A good MAC protocol should gracefully accommodate such network changes. Other typically important attributes including fairness, latency, throughput and bandwidth utilization may be secondary in sensor networks.

II. Related Work

The existing wireless MAC protocols such as IEEE 802.11 is not suitable for the sensor network application because these are battery powered and recharging is expensive and also not possible. Sensor S-MAC [2] was the first protocol specially designed for the wireless sensor network in 2002. In this sensor node periodically goes to the fixed listen/sleep cycle. A time frame in S-MAC is divided into to parts: one for a listening session and the other for a sleeping session. Only for a listen period, sensor nodes are able to communicate with other nodes and send some control packets such as SYNC, RTS (Request to Send), CTS (Clear to Send) and ACK (Acknowledgement). By a SYNC packet exchange all neighboring nodes can synchronize together and using RTS/CTS exchange the two nodes can communicate with each other. A lot of energy is still wasted in this protocol during listen period as the sensor will be awake even if there is no reception/transmission.

Timeout T-MAC [3] is the protocol based on the S-MAC protocol in which the Active period is preempted and the sensor goes to the sleep period if no activation event has occurred for a time ‘Ta’. The event can be reception of data, start of listen/sleep frame time etc. The time ‘Ta’ is the minimal amount of idle listening per frame. The interval $Ta > Tci + Trt + Tta + Tct$ where Tci is the length of the contention interval, Trt is the length of an RTS packet, Tta is the turn-around time (time between the end of the RTS packet and the beginning of the CTS packet) and Tct is the length of the CTS packet.

The energy consumption in T-MAC is less as compared to S-MAC. However the latency of T-MAC is more as compared to S-MAC. The proposed scheme takes

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in to account both energy consumption and latency.

III. PROPOSED MAC PROTOCOL

In the proposed MAC protocol, the sensor duty cycle is changed based on the network load. If the traffic is more than the duty cycle will be more and for low traffic the duty cycle will be less. The network load is identified based on the messages in the queue pending at a particular sensor. The control packet overhead is minimized by reducing the number and size of the control packets as compared to those used in the S-MAC protocol.

A. Nodes Synchronization

The synchronization of the neighboring sensor nodes is done using the SYNC packet as is done in S-MAC [2] protocol. This SYNC packet contains the address of the sender and the time of its next sleep. After deployment a sensor node starts by waiting and listening. If it hears nothing for a certain amount of time, it chooses a frame schedule and transmits a SYNC packet. If the node, during startup, hears a SYNC packet from another node, it follows the schedule in that SYNC packet and transmits its own SYNC accordingly. The synchronization table is maintained by all the sensor for its neighboring nodes. Upon reception of the SYNC packet the synchronization table is updated and the timer is adjusted accordingly.

B. Modified Data and Control Packets

The data and control packets in the wireless sensor networks are broadcasted. These packets apart from the frame control, duration, cyclic redundancy check contains the source & destination address [6] which have been removed as every node is the recipient. This removal of the source and destination address saves up to 50% of the control packet overhead.

Moreover some of the control packets such as SYNC and RTS has been combined in to one control packet SYNCrts (Fig. 1(d)) generated by combining SYNC packet Fig. 1(b) and RTS packet Fig. 1(c). This reduces the packets overhead and finally contributes in the reduction of the energy consumption and latency.

Bytes 2	2	6	6	6	2	6	0-2312	4
Frame Control	Duration	Addr1	Addr2	Addr3	Seq. Control	Addr4	Data	CRC

Fig 1. (a). IEEE 802.11 MAC Frame Format

Bytes 2	6	7	2	4
Frame Control	From Addr	Sleep Time	Duty Cycle	CRC

Fig. 1(b). SYNC Packet

Bytes 2	2	6	6	4
Frame Control	Duration (NAV)	To Addr	From Addr	CRC

Fig. 1(c). RTS Packet

Bytes 2	2	6	6	7	2	4
Frame Control	Duration (NAV)	To Addr	From Addr	Sleep Time	Duty Cycle	CRC

Fig. 1(d). SYNCrts Packet (Combined from Fig 1(b) and 2(c))

Bytes 2	2	6	4
Frame Control	Duration (NAV)	To Addr	CRC

Fig. 1(e). CTS Packet

Bytes 2	2	6	4
Frame Control	Duration (NAV)	To Addr	CRC

Fig. 1(f). ACK Packet

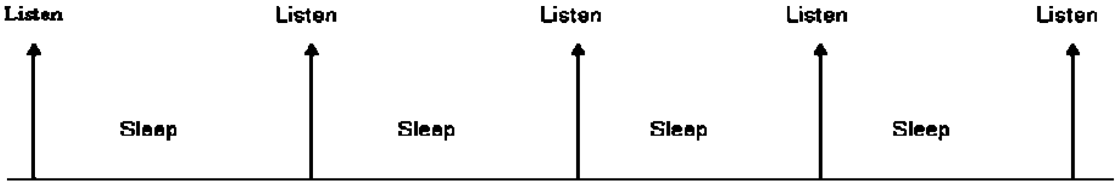

Fig. 2(a). Original Duty Cycle

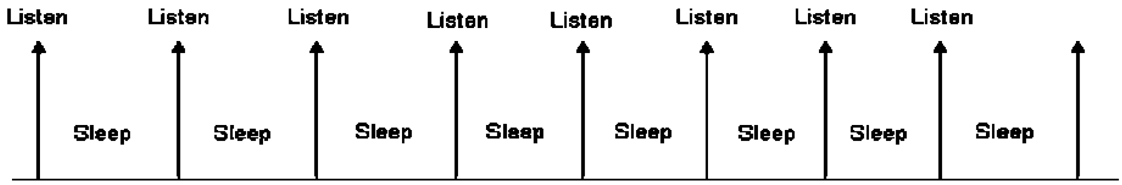

Fig. 2(b). Increased Duty Cycle

C. *Adaptive Duty Cycle*

The S-MAC protocol which has fixed duty cycle is energy efficient but this efficiency is achieved at the expense of compromise in the latency. In the proposed protocol each sensor keeps track of the traffic load based on the number of messages in its queue. When a message is received, the counter is increased and when it is transmitted the counter is decreased. If the message counter is greater than a threshold (COUNTthres), then the duty cycle is increased and the changed duty cycle is reported to the neighboring sensor in the SYNCrts packet. The neighboring sensor on the reception of SYNrts packet checks if its queue also contains message more than the COUNTthres, it also increases it duty cycle. If not, it simply updates the synchronization table and continues with the original duty cycle. When the traffic is less and so when message counter is less than COUNTthres, the duty cycle is decreased. The sensor reports the changed duty cycle to its neighboring nodes.

In this scheme all the nodes need not have the same duty cycle. The original duty cycle is still valid as the new duty cycle is the multiple of the original duty cycle. If the original duty cycle is 15%, the increased duty cycle will be 30%.Similarly when the load is less the duty cycle will be reduced from 30% to 15%.

In S-MAC protocol the synchronization among the sensors is achieved because of the common sleep-wakeup cycle i.e fixed duty cycle. In the proposed scheme on deployment all the sensor have the basic duty cycle. Once the traffic on a sensor becomes high it automatically increases it duty cycle by listening again during sleep time. So the sensor gets more time to receive the packets. The original listen time remains unchanged. When the traffic is low, its duty cycle is decreased and the sensor stops sensing the channel during sleep interval. So it starts maintaining its original listen-sleep cycle.

D. *Evaluation and Simulation Results*

We have simulated the above scheme in the Network Simulator ns-2. The general simulation parameters are given in Table 1. In the simulation, no mobility is assumed. In our experimental simulation we performed test on a simple two-hop network topology as illustrated in Fig. 3. We vary the traffic load by changing the packet inter-arrival time on the source node. The packet inter-arrival time changes from 1 Sec to 12 Sec. Under each traffic condition, the simulation is independently carried out for 10 times. In our simulations we evaluate the performance of our scheme and compared it with the standard S-MAC with 15% duty cycle & T-MAC protocols.

The comparative aggregate energy consumption of nodes is shown in Fig. 4. Energy consumption of a node is obtained by calculating the total transmit, receive, idle and sleep time of the radio. The energy consumption of the proposed MAC protocol is less than S-MAC protocol. This is because of the reduction in the size and number of the control packets. The energy consumption is however comparable to that of T-MAC protocol in which there is premature termination of listen interval when no event is expected to occur.

The latency behavior of the different MAC protocols is shown in Fig. 5. The latency of the proposed MAC protocol is less than both S-MAC and T-MAC protocol because of adaptive adjustment of the duty cycle based on the network traffic.

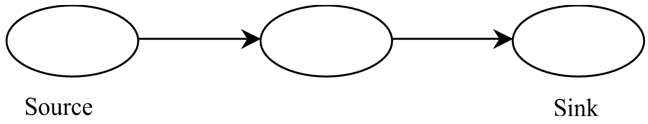

Fig. 3. Two-hop Network Topology Used in Experiment

Table 1: Parameters of MAC Implementation on NS-2

S. No	Parameter	Value
1.	Channel Bandwidth	20 kbps
2.	Control packet length	10 bytes
3.	Data packet length	Up to 250 bytes
4.	MAC header length	10 bytes
5.	Contention window for SYNCrts	31 slots
6.	Contention window for data	63 slots
7.	Slot Time	1 ms
8.	Power consumption for transmission	36 mW
9.	Power consumption for reception	14.4 mW
10.	Power consumption for sleep	15 µW

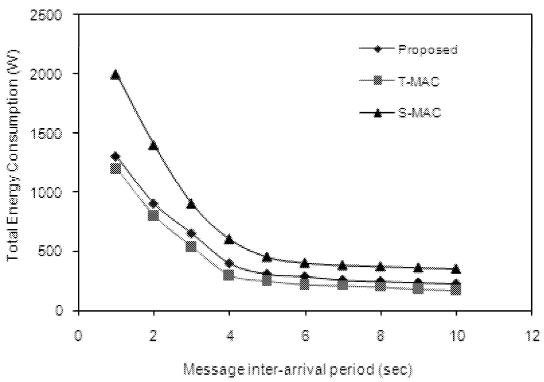

Fig.4. Aggregate Energy Consumption

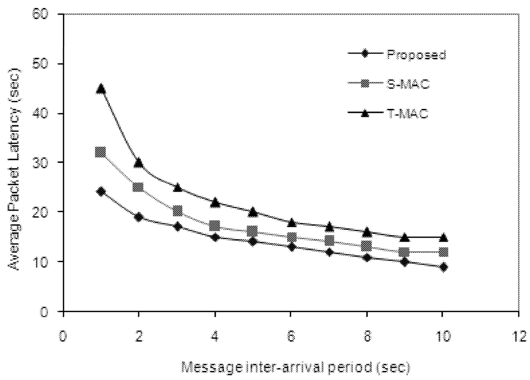

Fig.5. Latency Behavior

IV. CONCLUSION

In this paper we proposed a Medium Access Control (MAC) scheme for the wireless sensor network. This scheme is based on the concept of listen/sleep mode cycle like S-MAC. The S-MAC protocol achieves the energy efficiency at the expense of sensor latency and may not be suitable for the delay sensitive medical and defense applications.

The proposed scheme is good for applications where apart from energy efficiency there is need for lower latency. In the proposed scheme the latency is less because of the adaptive adjustment in the sensors duty cycle based on the network traffic conditions. The energy consumption has been reduced because of the reduction in the number and size of the control packets. As part of our future work, we plan to incorporate node mobility.

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