AN ENERGY EFFICIENT TDMA BASED MAC PROTOCOL FOR WSN USING ADAPTIVE TRANSMIT POWER SCHEME

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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. Efficient MAC protocols have a great effect on the power consumption for wireless sensor networks as they affect the efficiency of controlling and exchanging data. Energy conservation and self-configuration are primary goals, while per-node fairness and latency are less important in Wireless sensor Network. The paper presents measurement results of TDMA based MAC protocol which also uses NOAH, no ad hoc routing agent. The simulation is performed by using Network simulator 2 (NS2) and finally the results are compared with the SMAC which shows TDMA (NOAH) based MAC protocol that uses adaptive power transmit scheme saves upto 34 to 69% energy in comparison of SMAC protocol.

***Key Words*—wireless sensor network, SMAC, TDMA, NOAH, MAC and energy efficiency.**

I. INTRODUCTION

Improvement in hardware technology has resulted in low-cost sensor nodes which are composed of a single chip with embedded memory, processor, and transceiver. Low power capacities lead to limited coverage and communication range for sensor nodes compared to other mobile devices. Hence, for example in target tracking and border surveillance applications, sensor networks must include a large number of nodes, to cover the target area [1].

In TDMA, all the nodes transmit data with a fixed power level, no matter how close the involved nodes are. In order to reduce the energy consumption, an adaptive transmit power scheme is used. When a node receives a schedule broadcast from the others, it knows that the source is its neighbor and will update its neighbor list as well as schedule table if needed, an important action is done at the same time, the node will also measure the received power to evaluate the approximate distance from the source, and then adaptively decide the appropriate transmit power level and for determining transmit power Two-ray propagation model is used.

Wireless sensor networks (WSNs) have widely been used in many fields such as environmental monitoring, intelligent building management and product quality monitoring, etc. They can provide an easier interaction between man, machine and environment, which make our life easier [2]. In most WSN applications, however, nodes are usually powered by batteries and the nodes will become inactive, even more to losing their sensing and communication functionalities when energy is depleted. The transmission distance in WSNs is about 100m~1000m and it will be shortened by the reinforced concrete wall. This problem can be solved by multi-hop way. Therefore, it is of great importance to increase the reach of communication range and it is also of great importance to reduce the energy consumption of WSNs and prolong the network lifetime in the practical applications [3].

The medium access control protocols for the wireless sensor network have to achieve two objectives. The first objective is the creation of the sensor network infrastructure. A large number of sensor nodes are deployed and the MAC scheme must establish the communication link between the sensor nodes. The second objective is to share the communication medium fairly and efficiently [3].

A. *Attributes of a Good MAC Protocol*

To design a good MAC protocol for the wireless sensor networks, the following attributes are to be considered [4].

(i) Energy Efficiency: The first is the energy efficiency. The sensor nodes are battery powered and it is often very difficult to change or recharge batteries for these sensor nodes. Sometimes it is beneficial to replace the sensor node rather than recharging them.

(ii) Latency: The second is latency. Latency requirement basically depends on the application. In the sensor network applications, the detected events must be reported to the sink node in real time so that the appropriate action could be taken immediately.

(iii) Throughput: Throughput requirement also varies with different applications. Some of the sensor network application requires to sample the information with fine temporal resolution. In such sensor applications it is better that sink node receives more data.

ISBN: 978-93-83758-09-8

(iv)Fairness: In many sensor network applications when bandwidth is limited, it is necessary to ensure that the sink node receives information from all sensor nodes fairly. However among all of the above aspects the energy efficiency and throughput are the major aspects. Energy efficiency can be increased by minimizing the energy wastage.

B. *Major Sources of Energy Wastes*

Major sources of energy waste in wireless sensor network are basically of four types [4] [5].

(i) Collision: The first one is the collision. When a transmitted packet is corrupted due to interference, it has to be discarded and the follow on retransmissions increase energy consumption. Collision increases latency also.

(ii) Overhearing: The second is overhearing, meaning that a node picks up packets that are destined to other nodes.

(iii) Packet Overhead: The third source is control packet overhead. Sending and receiving control packets consumes energy too and less useful data packets can be transmitted.

(iv) Idle listening: The last major source of inefficiency is idle listening i.e., listening to receive possible traffic that is not sent. This is especially true in many sensor network applications. If nothing is sensed, the sensor node will be in idle state for most of the time. The main goal of any MAC protocol for sensor network is to minimize the energy waste due to idle listening, overhearing and collision.

II. RELATED WORK

In WSNs, the medium access layer controls the radio, and it has a large impact on the overall energy consumption. Although the research field of WSNs is relatively new, some interesting studies to MAC protocols for this type of networks can be found in literature. In this section we will describe some of these protocols e.g. SMAC, TMAC, LMAC and EMAC [4].

The sensor-Mac (SMAC) protocol [4] recognizes two phases in transceiver usage of network nodes: a listen period and a sleep period. In the sleep period, the nodes turn off their power consuming transceiver. After the sleep period, the nodes wake-up and listen whether communication is addressed to them, or they initiate communication themselves. This implies that the sleep and listen periods should be (locally) synchronized between nodes. Because the protocol is carrier sense multiple access with collision detection (CSMA/cd) based in the listen period, synchronization does not have to be very strict and nodes can use their sleep period as well for communication if needed. To prevent collisions of short "SYNC" messages (used for synchronization), which only contain a identification number of the sender and the next time nodes goes to sleep, the SMAC protocol divides the listen period in two sections. The first part is reserved for SYNC messages and the other part is reserved for request to send (RTS) messages. The SMAC protocol is also capable of transmitting Omni cast messages [4].

Timeout T-MAC [3] is the protocol based on the S-MAC protocol in which the Active period is pre-empted and the sensor goes to the sleep period if no activation event has occurred for a time 'Ta' as shown in Fig. 2. 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 $T_a > T_{ci} + T_{rt} + T_{ta} + T_{ct}$ where T_{ci} is the length of the contention interval, T_{rt} is the length of an RTS packet, T_{ta} 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 the Timeout TMAC protocol is less than the Sensor S-MAC protocol. But the Timeout T-MAC protocol has high latency as compared to the S-MAC protocol [6].

LMAC is a TDMA-based protocol for WSNs that give nodes the opportunity to communicate collision-free [8].TDMA protocols are centralized or distributed scheduled TDMA systems provide a natural way to conserve energy [6]. TDMA-based protocol divides time into time slots. Each slot can be assigned by only one node and this node controls over this time slot, so each node can use its own time slot to transfer data without having to content for the medium or deal with energy wasting collision of transmissions. However, it requires accurate time synchronization between the access point and the individual nodes to ensure that a node can be waked up exactly at the start of "its" slots. Therefore, TDMA based protocols need a good synchronic scheme. Such schemes are not easy to be implemented in dynamic WSNs.

The TDMA-based EMACs protocol divides time into *time slots*, which nodes can use to transfer data without having to content for the medium or having to deal with energy wasting collisions of transmissions. A node can assign only one slot to itself and is said to control this slot. After the frame length, which consists of several time slots, the node again has a period of time reserved for it. A time slot is further divided in three sections: *Communication Request* (CR), *Traffic Control* (TC) and the *data* section. In the CR section other nodes can do requests to the node that is controlling the current time slot. Nodes that have a request will pick a random start time in the short CR section to make their request. These messages are comparable to RTS messages in SMAC. Communication in this section is not guaranteed collision-free. Nodes that do not have a request for the current slot owner, will keep their transceiver in a low power state during the entire CR section.
The controller of a time slot will always transmit a TC message in the time slot. When a time slot is not controlled by any node, all nodes will remain in sleep state during that time slot [4].

III. PROPOSED WORK

The concentration of this work is on the protocols' ability to transfer data as efficiently as possible; the communication

ISBN: 978-93-83758-09-8

protocol in each cluster relies on the cluster head. It is developed to be pre-scheduled and every node in the cluster only transmits in its time slot and sleeps in other time-slot. Thus, it avoids collision.

Sensors equipped with transceiver, processor and memory will be deployed by the millions. Hence the costs of a single smart sensor must be at a minimum. This does not only translate to scarce resources like energy and memory in the sensors, but also to complexity of the hardware. Currently, multi-channel transceivers are available on the market, but they are still higher priced than single channel versions.

During the design of the medium access protocol, we assumed a single channel transceiver, which has three operational states: transmit, receive and standby. Typically, transmitting consumes more power than receiving and standby lies beneath the power consumption of receiving by a factor 1,000 or more. In table 3.1 summarizes some parameters of a transceiver we use for simulation. These parameters are also used in our physical layer model in the simulator to obtain network lifetime results.

We have presented energy efficient and collisions free MAC layer protocol for sensor networks along with adaptive transmit power mechanism which helps in decreasing the energy wastage. Collision free network is achieved by using TDMA scheme. The approach promotes time-based arbitration of medium access in order to limit signal interference among the transmission of sensors. Time slots are optimally assigned to communicating sensors within the sensor network to achieve efficient utilization of the energy resources. The presented slot assignment mechanism conserves sensor's energy by minimizing the number of collision. Packet loss due to collisions is absent because two nodes do not transmit in the same slot. Although packet loss may occur due to other reasons like interference, loss of signal strength etc. No contention mechanism is required for a node to start sensing its packets since the slots are pre-assigned to each node. No extra control overhead packets for contention are required.

In TDMA, all the nodes transmit data with a fixed power level, no matter how close the involved nodes are. In order to reduce the energy consumption, an adaptive transmit power scheme is used. When a node receives a schedule broadcast from the others, it knows that the source is its neighbor and will update its neighbor list as well as schedule table if needed, an important action is done at the same time, the node will also measure the received power to evaluate the approximate distance from the source, and then adaptively decide the appropriate transmit power level and for determining transmit power Two-ray propagation model is used. The equation of this model which gives us the received power is

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4}$$

$P_r(d)$ is the received power given at transmitter-receiver separation of d,
P_t is the transmit power,
G_t is the gain of the transmitting antenna,
G_r is the gain of the receiving antenna,
h_t is the height of the transmitting antenna above ground,
h_r is the height of the receiving antenna above ground and
d is the distance between the transmitter and the receiver.
If the interference comes in the path of the signal to be received, the signal is attenuated as d^4.

Network field	500 m × 500 m
Channel Type	Wireless Channel
Propagation model	Two ray ground
Antenna Model	Omni-directional
Number of sensors	50
Simulator	NS-2.29
Number of sinks	1
Transmission range	90m-250m
packet size	64 bytes
Transmit power	15mW
Receive power	13mW
Initial battery power	100j
MAC layer	SMAC/TDMA
Simulation time	300 s

Table 5.1 Simulation parameters

In addition, we have used NOAH i.e no ad hoc routing agent routing protocol, by implementing the NOAH protocol that allows direct communications (unlike AODV, DSR, ...) between wireless nodes, or between base stations and mobile nodes and add no routing packet while communication. The proposed MAC protocol has been validated through simulation and shown to have positive impact on energy consumption and other contemporary network performance metrics (throughput and average delay).

IV. SIMULATION AND RESULTS

For analyze, the simulations have been performed using Network Simulator 2 version 2.29. It is scalable and open source used for the simulation behaviors of wired or wireless network functions and protocols [9]. Our simulation network consists of 50 sensor nodes that are randomly scattered in the square field of 500 * 500.the simulation parameters shown in table 1.

Energy consumption, throughput, and end-to-end delay are the main issues in wireless sensor network. So, the proposed work focus on these issues. This thesis work uses the TDMA

ISBN: 978-93-83758-09-8

based MAC protocol, for Energy Efficient wireless sensor network.

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The following are the result analysis of this work protocol. The above fig: 1 depicts the energy consumption of the simulation which is quiet reliable and efficient for the wireless sensor network. Initially the remaining energy is

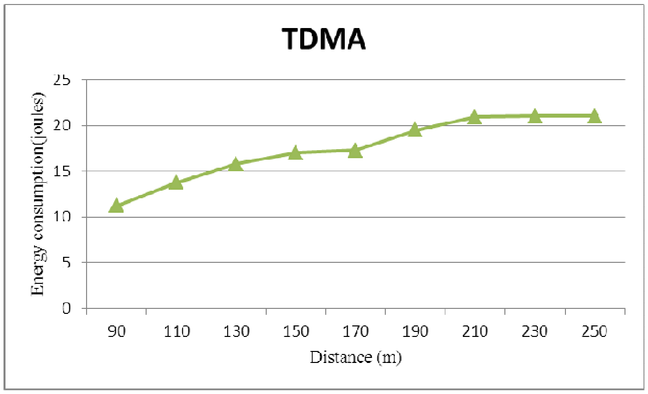

Fig. 1: Remaining energy for TDMA MAC

less but as transmission range increases the energy wasted in unsuccessful transmission reduces to a small amount, most of the source- destination pairs are connected and this increase in transmission range will decreases the number of hops between a given source-destination pair and hence the remaining energy increases or we can say that energy consumption reduces of a wireless sensor network

Comparison with SMAC

After simulations on NS-2, it came to know the purposed MAC protocol has better results than previous SMAC protocol in terms of Energy Consumption, average delay and throughput. Fig 2 describes the comparative analysis of energy consumption for SMAC and purposed TDMA MAC (NOAH) protocol.

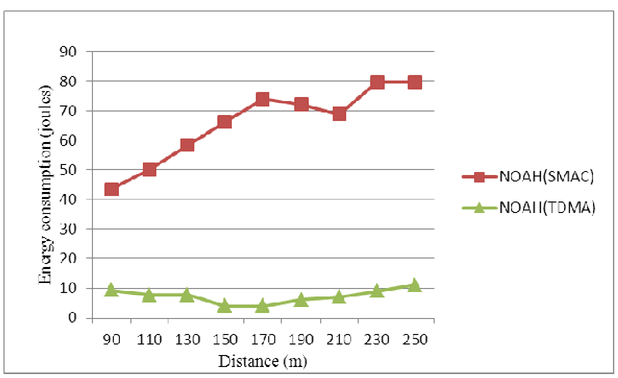

Fig. 2: Comparative Energy consumption for SMAC and TDMA MAC (NOAH)

We note that TDMA (NOAH) outperforms SMAC in terms of energy consumption. TDMA (NOAH) has around 34 to 69% lower energy consumption as compared to SMAC, as seen in Table 5.2. The reason is that although both MACs use sleep and wakeup cycle to save energy, but in SMAC collision and contention mechanism consumes a great amount of energy Also energy is wasted by SMAC through the retransmission which results from its collisions.

V. CONCLUSION

Wireless sensor networks have been drawing increased attention in recent years. Sensors are typically disposable and expected to last until their energy drains. Therefore, energy is a very scarce resource for such sensor systems and has to be managed wisely in order to extend the life of the sensors for the duration of a particular mission. Time based operation of sensor networks can conserve sensor's energy since it allows sensors to switch to low energy sleep mode while not transmitting and receiving messages.

The energy aware MAC protocol is based on TDMA and hence possesses the natural ability of avoiding extra energy wastage. The main advantages of a TDMA protocol are the following.

- Packet loss due to collisions is absent because two nodes do not transmit in the same slot. Although packet loss may occur due to other reasons like interference, loss of signal strength etc.
- No contention mechanism is required for a node to start sensing its packets since the slots are pre-assigned to each node. No extra control overhead packets for contention are required.

VI. FUTURE SCOPE

Future work includes parameter analysis and implementation on real sensor nodes. More tests will be done on larger scale. And cross layer design will also be taken into account to reduce more energy consumption

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ISBN: 978-93-83758-09-8

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