A New Uni-Scheduling Algorithm in S-MAC based Wireless Sensor Networks

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Abstract— In practice, a significant amount of power is spent for processing of transmission and reception of information in wireless sensor network (WSN). The variant rate of depletion of power in the sensing devices can hamper the network's efficient operation and therefore its lifetime. There are normally, in practical systems, certain considerations taken at each layer to prolong the network lifetime. This paper investigates one of the Medium Access Control (MAC) protocols called Sensor-MAC (S-MAC) protocol. In S-MAC, the first task of WSN is to find the neighbor nodes and then broadcast its own schedule. Thus diversified schedules are generated in the network and at the end different schedule clusters are made. If a node exists on the border of these clusters, it fails to communicate with one another due to inconsistent listen time. Therefore, the border node adopts diversified scheduling to keep on the listening mode for a longer period of time. In this paper, the authors have proposed a new unified scheduling algorithm to increase the lifetime of the border node and have evaluated its performance through simulation. The simulation results show that the border node has consumed less power for larger as well as smaller networks with the proposed approach.

Keywords- S-MAC (Sensor-MAC) protocol, SN (Sensor Nodes), Wireless Sensor Network (WSN), Uni-Scheduling packets

I. INTRODUCTION

Wireless sensor network (WSN) has emerged as one of the potential applications of the modern technology. It is used for a wide range of purposes such as environment monitoring, smart spaces, medical systems and robotic exploration. The WSN has become a hot issue in research which is regarded as one of the ten influencing technologies in the 21st century [1].

The WSN is made up of Sensor Nodes (SN) which are actually micro devices and operated upon a predetermined set of instructions. These devices can only provide short range radio communication and have limited processing or computational capabilities. The problem of these SN devices become very serious when their batteries are non-rechargeable in physical environment as a significant amount of power is spent for processing the information. The variant rate of depletion of energy in the nodes can seriously hamper the network's efficiency and therefore its lifetime. The major source of energy loss that takes place in WSN is collision or corruption during broadcasting of packets. The next source of energy waste is idle listening, that is, listening to an idle channel in order to receive any possible traffic. The third case of energy loss is overhearing of a node to receive some packets that are destined for other nodes. The use of control packets overhead to setup data transmission is another source of energy loss. The last case is over emitting, which is caused by transmission of message when the destination node is not ready.

Numerous types of energy efficient protocols such as TDMA and MAC [2] are proposed to prolong the lifetime of WSN. However, S-MAC (Sensor-MAC) protocol [3] has shown better performance in minimizing power consumption. Yan-Xiao Li et al. [6] evaluated the performance of S-MAC protocol by improving latency and jitter. They had achieved the results by varying the duty cycle of the S-MAC. Though S-MAC protocol showed better performance, it had some problems to initialize listen and sleep scheduling. To overcome that problem W. Lee et al [5] designed an algorithm to minimize energy consumption of border nodes by using unified schedule and modifying the synchronization packet. If collision happened due to large packet size, the SN would incur delay and go through idle listening time. E. M. Shakshuki et al. [7] used a unified scheduling approach where the network got synchronized under a single schedule. Though the longevity of the WSN life had increased to some extent but the border nodes die out quickly as they stayed in the listening state for longer period of time.

In this paper, an algorithm has been proposed to overcome the above limitations using synchronization of sensor nodes under a unified schedule. The schedule is broadcasted periodically from the border nodes so that all the sensor nodes can communicate with each other under a single schedule. In this way the prolong life of all the nodes in the network will increase.

II. S-MAC PROTOCOL

S-MAC protocol is a medium access control protocol which is widely used in WSNs for energy conservation. It retains flexibility of the contention-based protocols similar to IEEE 802.11. There are 3 major energy consumptions in S-MAC

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that are identified. They are: a) Collision which results in energy waste due to retransmission of collided packets. b) Overhearing occurs when a node listens to transmissions which are not intended for it. c) Idle listening occurs when a node senses the channel to receive any possible data that is not sent.

The communications between SN take place when S-MAC protocol exchange packets that starts with Carrier Sense (CS) to avoid collision. Then followed by Read to Send and Clear to Send (RTS/CTS) packets are exchanged for unicast data packets shown in Fig-1. Upon successful exchange of these packets data transmission takes place.

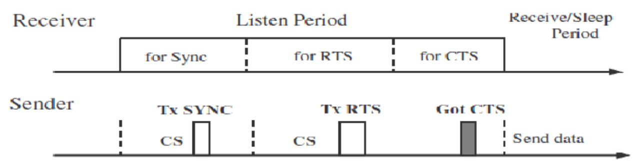


Fig.-1: S-MAC Messaging Mechanism

When a WSN is embedded with S-MAC protocol a node is in the sleep state to reduce collision and overhearing. The node basically stays in the listen state for 10 seconds in every 2 minutes [4].It wakes up when its neighbor's transmission ends and can relay the packets if required. Since all the SN have their own sleep schedules, periodic sleep may results in latency. The latency caused by periodic sleep is called sleep delay. Schedules are periodically exchanged by broadcasting SYNC packets among neighboring nodes. Due to inconsistent of time cycle different virtual clusters are formed. The communication between these virtual clusters takes place when a common node between them adopts both the schedules and is called the border node. In this way, a border node is listening for a longer period of time and dies out quickly

There are two main reasons of multiple scheduling in a single network. Firstly, when nodes establish their own schedules, some nodes are situated far away and cannot hear each other schedules. Secondly, if two nodes broadcast their schedules at the same time and collision may take place. In both the situations the nodes must now choose their own schedules.

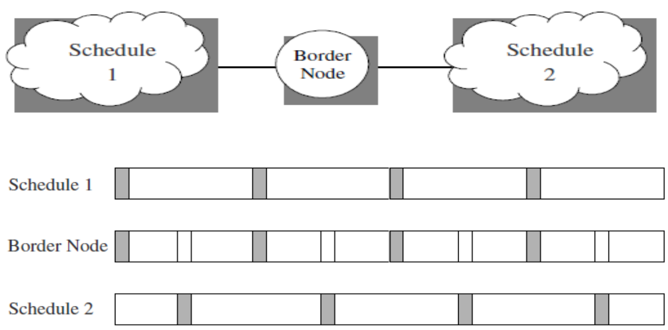


Fig.-2: Border node is adopting and handling both the schedules

III. ALGORITHM DEVELOPMENT

Our main focus is to implement a scheduling scheme so that all the sensor nodes can communicate with each other at the same time. In order to synchronize the whole WSN quickly our proposed algorithm is performed from the constructed border nodes and data packets can be transferred between the different virtual clusters.

In S-MAC protocol a node maintains a Schedule Table, which stores its own schedule and schedules of all its neighbors. Normally, a node is operated based on its primary schedule but in the case of a border node, it is operated based on the number of schedules in its Schedule Table.

The construction of the border node is performed after considering the following conditions. Firstly, if a node has its own schedule and receives a SYNC packet from a node with larger ID, it will not adopt the latter schedule. Secondly, the Neighbor list Table is updated after updating the Schedule Table in order to know the entire active neighbors surrounding a node. Thirdly, the broadcasting of Uni-Scheduling packets is performed after the construction of a border node. The construction of a border node takes place during the listening period and performs the following tasks as shown in Fig-3. Fourthly, the whole synchronization procedure takes place during the listening period.

After the construction of the border nodes, the next task is to set up a common schedule across the WSN so that all the nodes can be unified under a single schedule instead of heterogeneous schedules.

The unified scheduling algorithm is shown in Fig-4. Before going to analyze the proposed algorithm several conditions are considered as follows:

i.) All the nodes are in the fixed position.
ii.) The adaptive listening of S-MAC protocol is not applied for this simulation.
iii.) All the nodes are synchronized according to the schedule in the Uni-Scheduling packets.
iv.) The Uni-Scheduling packets are broadcast periodically from the border nodes.
v.) If a node is running under uni-schedule and if it still receives any more Uni-Scheduling packets, it discards all the latter packets.

The nodes deal with Uni-Scheduling packets in the proposed algorithm and the transmission of these packets to all the nodes are done with using three types of timers. The timers D-timer, B-timer and P-timer are used to change the transition state of the nodes. All the nodes have to go through three transition state (LISTEN, AWAKE and RUN STATES) before they are synchronized.

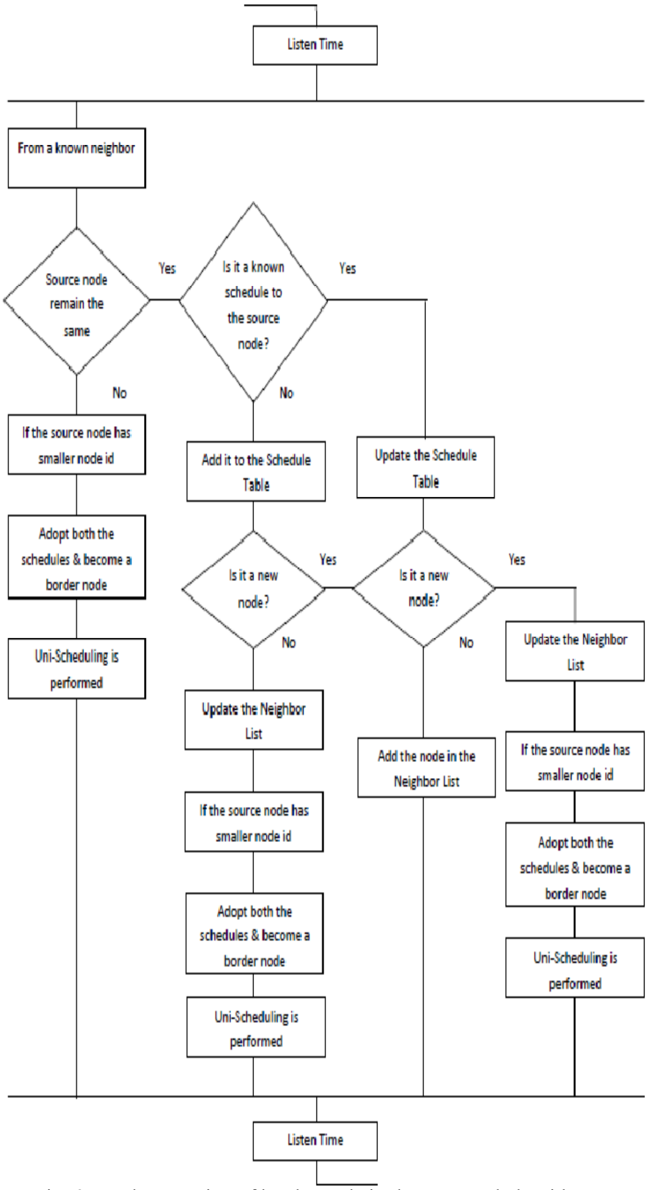


Fig.-3: Implementation of border node in the proposed algorithm

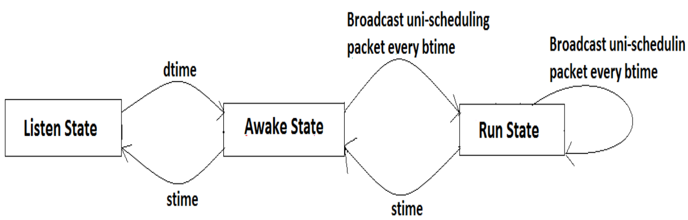


Fig.-4: State transition for Proposed Uni-Scheduling

The detail explanation of the different transition state and the timers are given below.

1.) The LISTEN STATE is the initial node state in which the node works in the listen state. The state is periodically changed to AWAKE STATE according to the D-time.

2.) In the AWAKE STATE, the border nodes adopt the uni-schedule and set the schedule as their primary schedule in the Schedule Table. Then Uni-Scheduling packets are broadcasted periodically to all the nodes in the network after every B-time. No data packets transmission is performed until all the nodes receive Uni-Scheduling packets.

3.) After receiving the Uni-Scheduling packets the node's state changes to the RUN STATE. In the RUN STATE the node will sense if its neighbor is synchronized under uni-schedule. When all the nodes are synchronized under uni-schedule, the DATA packet transmission will take place.

4.) The D-timer is used to change the transition state of the node periodically from the LISTEN STATE to the AWAKE STATE.

5.) The B-timer is used so that Uni-Scheduling packets are broadcasted periodically from the border nodes to all the other nodes in different virtual clusters.

6.) The P-timer is used to set a time of which the nodes waits to receive the subsequent Uni-Scheduling packets and if a node failed to receive any Uni-Scheduling packets, the node will move back to the previous state after the timer expires.

The Uni-Scheduling packet as shown in Fig.-5 contains a scheduling time and is broadcasted from the border nodes to the whole sensor network. According to this signal, the nodes reset their timers and set the uni-schedule as their primary schedule in their Schedule Table. After that all the nodes are synchronized and data transmission begins.

Once, all the nodes follow this proposed uni-scheduling scheme, the whole network gets to be synchronized under a single schedule.

Border node ID	Relative Scheduling Time

Uni-Scheduling Packet

Fig.-5: The structure of Uni-Scheduling Packet

IV. NETWORK SETUP

Table-1: PARAMETERS FOR SIMULATION

Parameter	Values
RTS/CTS/ACK Size	10 Bytes
Sync Packet Size	9 Bytes
Uni-Scheduling Packet Size	9 Bytes
Simulation area	1000m x 1000m
Routing Protocol	DSR
Listen Time	0.5 sec
D-Time, B-Time & P-Time	5 sec, 1sec & 250 sec
Simulation Time	1000 sec
Duty cycle	10%
Initial Energy	100 J
Tx and Rx Power	10 and 20

The proposed scheme is simulated in the Network Simulator-2 (ns-2) [8] under Linux environment. The platform for simulation has provided us the perfect and exact visualization to the sensor nodes. In ns-2, the TCP Agent is attached to all the source nodes and TCP Sink Agent is attached to the biggest node in the environment. The DSR routing protocol is used because it provide loop-free routing and routing table updates are only sent whenever the network changes. The CBR traffic is considered for this simulation. The energy model used for our purpose is implemented in ns2 and shows the energy consumption during state transition. Two kinds of topologies are considered for the testing purpose- multi-hop and random. The multi-hop scenario consists of 10 nodes and the random scenario consists of 40 nodes.

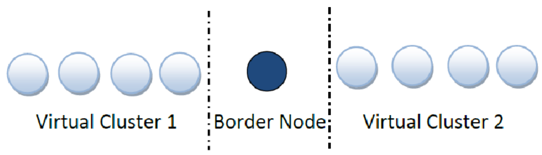


Fig.-6: Multi-hop scenario

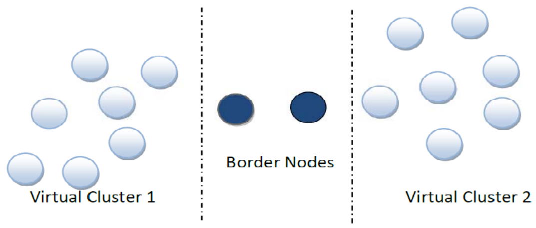


Fig.-7: Random Scenario

V. SIMULATION RESULTS & ANALYSIS

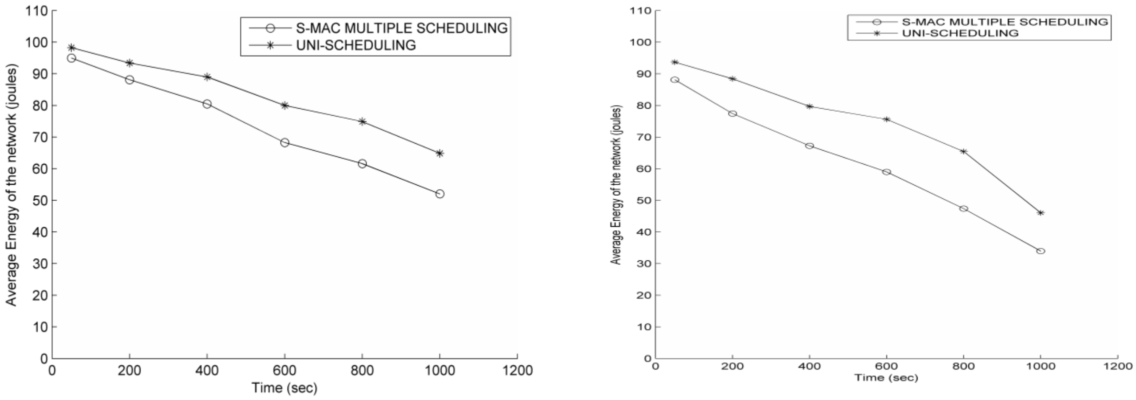
In this section, we present the results and analysis of our simulations on different topologies. The first section of graphs represents the energy consumption of the nodes and the second section of graphs represents latency in the overall network.

A. Energy Consumption

Fig.-8 shows the energy consumption of all the nodes in the network. In Fig. 8(a), it is seen that Uni-scheduling mechanism saves large amount of energy in compare to S-MAC with multiple scheduling. This is because less collision happened and most of the packets reached the destination node. Fig.8 (b) also shows that the network energy is higher in case of Uni-scheduling scheme. However, during the interval of 600 to 1000 seconds, the two curves come a bit closer. This is because some of the data packets are lost due to collisions and have to be re-transmitted again. Nevertheless, the proposed scheduling scheme still performed efficiently when compared with the S-MAC scheduling method. This means that Uni-Scheduling is more appropriate for a random network scenario.

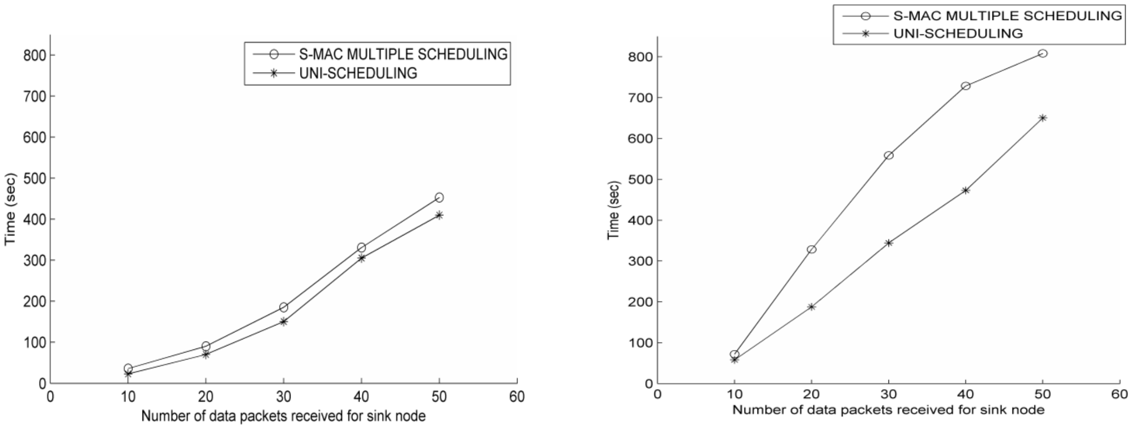
B. Latency

The other characteristic that is of concern is end-to-end delay. Latency in S-MAC is mainly caused by periodic listen schedule. There are many factors that can affect the latency of WSN, such as carrier sense delay, queuing delay, transmission delay propagation delay and back-off delay. However, we are concerned about the delay that is brought on by sleep/listen schedule. From Fig.-9 we can observe that latency is less when the sensor nodes are performing under Uni-scheduling. Again we see simple network topology has less latency as there is few collision, overhearing and re-transmission. Thus the graphs of Fig.-9(a) are almost parallel to each other's. However, in Fig.-9(b) the latency of S-MAC multiple scheduling is much higher than Uni-scheduling. This is due to the complexity of the WSNs and since the network is random, its behavior is unpredictable. Uni-scheduling does not completely eliminate the latency as heterogeneous schedules still exist in the network for border nodes construction.



(a) Multi-hop Scenario (b) Random Scenario

Fig.-8: Energy consumption of the network



(a) Multi-hop Scenario (b) Random Scenario

Fig.-9: Latency of the network

VI. CONCLUSION

The proposed scheme has unified the scheduling of S-MAC protocol to overcome the problem in diversified scheduling in wireless sensor network. The border nodes in between virtual clusters broadcast Uni-Scheduling packets which synchronize the network under a single schedule. The simulated results showed that there is a clear trade-off between network latency and energy consumption. However, the lifetime of the network increases in compare to the existing S-MAC protocol.

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