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Energy Proficient SMAC Protocol in Wireless Sensor Network

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ABSTRACT
Wireless Sensor Network (WSN) is a promising technology that has a wide range of potential applications. Such network consists of large number of distributed nodes that organized themselves into multihop WSN. Each node collects information as required and sends it to base stations. There is a major problem of energy consumption in WSN. As sensor nodes are located in remote areas without any personal assistance. In this paper, the proposed work is to analyze the energy consumption and its effect on data transmission using Sensor Medium Access Control (S-MAC) protocol. S-MAC protocol is used in WSN to reduce energy consumed by sensor nodes. Proposed work is to analyze energy consumption with different duty cycles in S-MAC protocol and its effect on throughput of network. The duty cycle is decided at which energy consumption is less compared to others and how much this is efficient to others. Similarly throughput and end to end delay is found at different duty cycles. Again duty cycle is found at which both the attributes are efficient.
Keywords - WSN, S-MAC, Energy Consumption in Wireless Sensor Network

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I. INTRODUCTION

Wireless Sensor Network consists of a large number of nodes which are situated in remote areas. These sensor nodes are distributed and form multihop sensor networks. There is lot of applications of WSN such as expert system, medical system, monitoring environmental conditional, robotic exploration etc. Each node is battery powered. It consist embedded processors for carrying out computation, some sensors for gathering data and sending to the gathering sink and low-power radios.

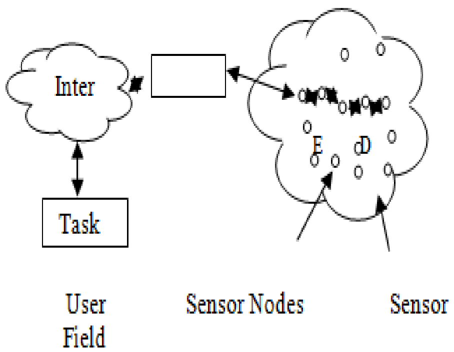

Fig. 1 Wireless Sensor Network

All these nodes perform a common task and coordinated to each other. All these nodes operated in a particular area for monitoring and collect physical attributes like temperature, humidity, pressure etc. The gathered data can be utilized for various decisions making for different applications like surveillances monitoring, habitat monitoring and system monitoring in various phenomenas[4]. Actuator network have many dispersed devices perform three essential services: first is to sensing physical and environment conditions. Second is to operate devices like switches, motors or actuators. Third is to securely and reliably communicate via wireless networks. These devices are used to low traffic monitoring and control applications rather than high data rate throughput.

II. RELATED WORK

Sensor nodes in WSN are deployed in ad-hoc fashion and these are very small. They can be produced in antagonistic environment or a large geographical are. So recharging sensor nodes is very difficult. So how can we prolong the life of sensor nodes? Power consumption is the biggest issue in WSN. This is significantly affected by communication between nodes. So the communication protocol between layers is designed in such a way that power consumption can be reduced. SMAC (Sensor Medium Access Control) protocol is designed to reduce power consumption. When there is no communication then sensor nodes should go into inactive mode and become active when certain action occurred. In sleep or inactive state, all radios become off, there is no consumption of energy. The main objective of S-MAC protocol is to reduce energy consumption, while underneath good scalability and collision avoidance. S-MAC protocol tries to reduce energy consumption from all the sources that have been acknowledged to cause energy waste as idle listening, collision, overhearing and control overhead.

A. Major source of energy wastes in Wireless Sensor Network

There are basically four major sources of energy waste in wireless sensor network [1][6].

Collision: When packet is transmitted then there is a possibility of interference and packet may loss. Due to this corruption, this packet should have to retransmit. This retransmission increase energy consumption.

Overhearing: Sometimes the packet may reach at a node that is not destination. This consumes energy, so this is also the reason of energy consumption.

Packet Overhead: When packet is transmitted then some unimportant packets may be transmitted with the main packet, this increase the energy consumption.

Idle listening: This is also a major factor of energy consumption as sometimes node is waiting for receiving the possible traffic that is not sent. This is called idle listening. Many times node has sensed nothing but still that is in idle state which is a reason of energy consumption.

III. S-MAC PROTOCOL

S-MAC stands for Sensor MAC, is a medium access control (MAC) protocol considered for wireless sensor networks. The basic idea behind S-MAC is very simple - nodes produce a sleep schedule for themselves that determines at what times to make active their receivers and when to set themselves into a sleep mode. S-MAC exploits the bursty profile of sensor applications to establish low-duty-cycle operation on nodes in a multihop network and to achieve significant energy savings.

Neighboring nodes are not essentially requisite to synchronize sleep schedules, although this will help to reduce overhead. However, they must at least distribute their sleep schedule information with others through the transmission of periodic SYNC packets. When a source node requests to send a packet to a destination node, it waits until the destination's get up period and sends the packet using CSMA with collision avoidance [3].

A. Sporadic Sleep and Listen Operations

Reducing energy consumption is the main objective of the S-MAC protocol. This can be done by avoiding idle listening.

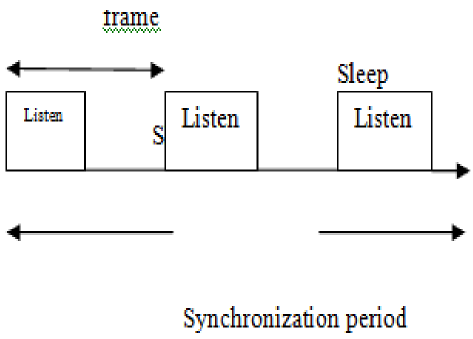

Fig 2 Periodic sleep and listen

This is achieved by establishing low-duty-cycle operations for sensor nodes. When nodes moves in sleep state then their radios becomes turned off completely and there is no power consumption. Nodes turn into active when there is traffic in the network. The basic periodic listen and sleep scheme is shown in Figure 2. According to this scheme, each node sets a wake-up timer and goes to sleep for the specified period of time. At the expiration of the timer, the node wakes up and listens to determine if it needs to communicate with other nodes.

The whole listen-sleep cycle is referred to as a frame. Each frame is characterized by its duty cycle, defined as the listening period to frame length ratio.

A.1 Choosing and Maintaining Schedules

Before each node starts its periodic listen and sleep, it requests to decide a schedule and swap it with its neighbors. Each node maintains a schedule table that stores the schedules of all its acknowledged neighbors. According to this schedule tables they communicate with neighboring nodes. [2].

A.2 Sustaining the Synchronization

Synchronization is very important among adjacent nodes in listen/sleep scheme. Though the long listen moment can accept reasonably huge clock drift, adjacent nodes still need to periodically update each other their schedules to put off long-time clock drift. The updating period can be relatively long. The measurements on our tested nodes show that it can be on the order of tens of seconds. Updating schedules is consummate by sending a SYNC packet. The SYNC packet is very short, and includes the address of the sender and the time of its next sleep.

B. Smash and Overhearing Prevention

Smash avoidance is a basic task of S-MAC protocols. S-MAC adopts a contention-based scheme. It is common that any packet transmitted by a node is received by all its neighbors even though only one of them is the intended receiver. Overhearing makes contention-based protocols less efficient in energy than TDMA protocols. So it needs to be avoided[1][3].

B.1 Smash Prevention

At a particular instant there are multiple senders. All may want to transmit to a receiver at the same time, there is a problem of smash (collision). This is necessary to compete for the medium to avoid collisions. Among contention based protocols, the 802.11 does a very good job of collision avoidance.

B.2 Overhearing Prevention

Our protocol S-MAC tries to prevent overhearing by letting interfering nodes go to sleep after they listen an RTS or CTS packet. Since DATA packets are normally much longer than control packets, the approach prevents bordering nodes from overhearing long DATA packets and the following ACKs. [3][5].

C. Duty Cycle

Since sensor nodes are battery-powered and may not recharge easily. Consequently, how to prolong the life time of the nodes is an important issue when designing protocol in wireless sensor network. However, lowering the energy consumption may result in higher latency. To address on such tradeoff the duty cycle is changed to improve S-MAC [1][3].

The duty cycle is defined as the ratio of listen period to a complete sleep and listen cycle. In S-MAC, the low-duty-cycle mode is the default operation for all nodes. Duty-cycle is a user-adjustable parameter in S-MAC, which determines the length of the sleep period in a frame. Changing the duty cycle will change the performance of S-MAC. Duty cycle can be adjusted by user from 1-100% to manage the length of sleep period. Usually the frame length is same for all the nodes.

IV. SIMUATION RESULTS AND ANALYSIS

In this chapter simulation results are carried out at different duty cycles like 5%, 10%, 20% and 30% for energy consumption, throughput and end to end delay in S-MAC and MAC protocol. The simulation results are shown in tables and corresponding graphs are drawn.

A. Simulation of Sensor-Medium Access Control protocol at different duty cycles

All experiments are carried out at four duty cycles as 5%, 10%, 20% and 30% for energy consumption, throughput and end to end delay in S-MAC protocol. The result has been taken at source node and sink node. Then increase the number of nodes upto eight and analyze the results. In this experiment 700 ms time is divided into 7 equal parts of 100 ms. For each attribute like energy consumption, throughput and end to end delay, the average simulation results for average 1-100 ms is found. Similarly average results are taken for average 100-200 ms, 200-300 ms, 300-400 ms, 400-500 ms, 500-600 ms and 600-700 ms. For reducing graph complexity, the average time as well as average results are taken. The major object of this experiment is to find the duty cycle at which energy consumption is efficient.

A.1 Energy consumption at 5%, 10%, 20% and 30% duty cycles in S-MAC protocol

In this experiment the initial energy E=1000 joules is taken for all 5%, 10%, 20% and 30% duty cycles. In below Table 1 the remaining or residual energy is shown.

Table 1 Residual energy at 5%, 10%, 20% and 30% duty cycles

Time (ms)	Duty Cycle/Residual Energy(joules)			
	5%	10%	20%	30%
100	942.291	961.874	973.510	972.685
200	903.833	937.691	945.594	939.088
300	872.749	914.448	915.324	901.616
400	839.308	887.653	886.308	866.119
500	806.752	859.214	857.705	826.327
600	773.115	835.757	825.606	793.495
700	733.996	805.0229	798.076	553.790

From Table 1 energy consumed at 5% duty cycle in first average 100 ms is highest.

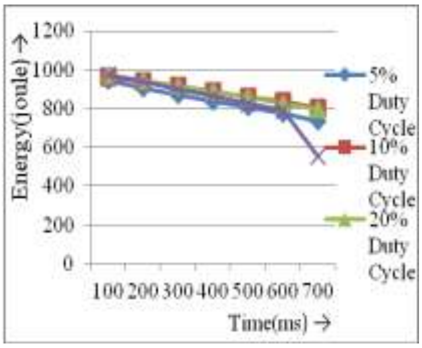

Fig. 3 Rate of Energy consumption at 5%, 10%, 20% and 30% duty cycle

The remaining average energy is 942.291 joules. X This is achieved by establishing low-duty-cycle operations for sensor nodes.

In Figure 3 it can be seen that least consumed energy is in 30% duty cycle. That is 27.315 joules. But this is slightly equal to 20% duty cycle, the consuming average energy is 26.490 joules at 20% duty cycle. As time increases energy consumption in 5%, 20% and 30% duty cycles are also increases. But in 10% duty cycle the energy consumption is decreases. At average 400 ms time remaining average energy at 5%, 10%, 20% and 30% duty cycles are 839.308 joules, 887.653 joules, 886.308 joules and 866.119 joules.

Finally at average 700 ms consuming energy difference at 10% and 30% duty cycles are increases. Remaining average energies at average 700 ms in 5%, 10%, 20% and 30% duty cycles are 733.996 joules, 805.0229 joules, 798.076 joules and 553.790 joules. It can be seen that consumption of energies are 266.004 joules, 194.9771 joules, 201.924 joules, 446.210 joules respectively. The consumption of energy at 10% duty cycle is least. In 10% duty cycle remaining energy is 80.6% which is the maximum in all four duty cycles.

A.2 Throughput at 5%, 10%, 20% and 30% duty cycles in S-MAC protocol

This section is carried out throughput at all four duty cycles like 5%, 10%, 20% and 30%. At starting average100 ms average throughput at 5%, 10%, 20% and 30% duty cycles are 0.548, 0.599, 0.870 and 0.836. Throughput is defined as the ratio of received size to difference between stop time and start time. Then this whole statement is multiplied by 8/1000. Then unit of throughput is kbps. This is shown below in Table 2.

Table 2 Throughput at 5%, 10%, 20% and 30% duty cycles

Time (ms)	Duty Cycles/Throughput(kbps)			
	5%	10%	20%	30%
100	0.548	0.599	0.870	0.836
200	0.452	0.472	0.457	0.469
300	0.445	0.451	0.431	0.444
400	0.445	0.447	0.429	0.445
500	0.444	0.443	0.429	0.427
600	0.438	0.444	0.423	0.430
700	0.440	0.440	0.400	0.420

These results are concluded that throughput between different duty cycles are different. Simulation results shown in Table 2, it can be seen that throughput at 20% duty cycle is best that is 0.87 and minimum throughput is at 5% duty cycle that is 0.548. This throughput is 0.34, greater than the second highest throughput.

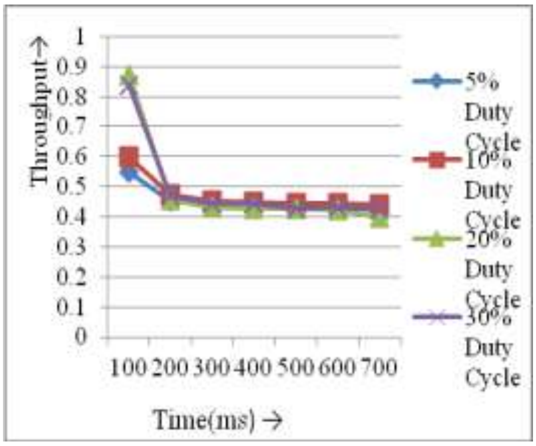

Fig 4 Rate of throughput at 5%, 10%, 20% and 30% duty cycles

In starting 30% duty cycle is better than 10%, as time increases this become less efficient than 10% duty cycle. In 5% duty cycle throughput is also better than 30 % duty cycle but a little bit less than 10%. At average 700 ms average throughput at 5%, 10%, 20% and 30% duty cycles are 0.440, 0.440, 0.400 and 0.420. Here 5% and 10% duty cycles have approximate same throughput. But before this 10% duty cycle have better throughput. Consequently, we can say that throughput is also better in 10% duty cycle.

A.3 End to end delay at 5%, 10%, 20% and 30% duty cycles in S-MAC protocol

From Table 3 shown below can be seen that average end to end delay at average 100 ms in 5%, 10%, 20% and 30% duty cycles are 53.77 ms, 19.07 ms, 6.69 ms and 3.94 ms. By the analysis it is found that 30% duty cycle is much better than all duty cycles including 10% duty cycle. Delay at 30% duty cycle is 3.94 ms which is less than delay 19.07 ms of 10% duty cycle. Although 20% duty cycle also has a less end to end delay but more than 30% duty cycle and the difference is 2.65 ms delays. But at average time 200 ms 20% duty cycle become much well than 30% duty cycle and the difference is 2.09 ms delays. At average 300 ms 30% duty cycle is much better than 20% duty cycle. During simulation time, end to end delay decrease consistently.

Table: 3 End to end delay in 5%, 10%, 20% and 30% duty cycles

Time (ms)	Duty Cycles/End to End delay(ms)			
	5%	10%	20%	30%
100	53.77	19.07	6.69	3.94
200	14.92	3.50	1.17	3.26
300	6.13	1.64	0.63	0.39
400	3.83	1.23	0.41	0.26
500	2.87	0.95	0.30	0.18
600	2.28	0.77	0.24	0.14
700	1.96	0.63	0.21	0.12

On the other hand at average 100 ms end to end delay at 10% duty cycle is more but this delay decrease consistently till the end. At average 700 ms, average end to end delay is 1.96 ms, 0.63 ms, 0.21 ms and 0.12 ms at all three duty cycles 5%, 10%, 20% and 30% respectively.

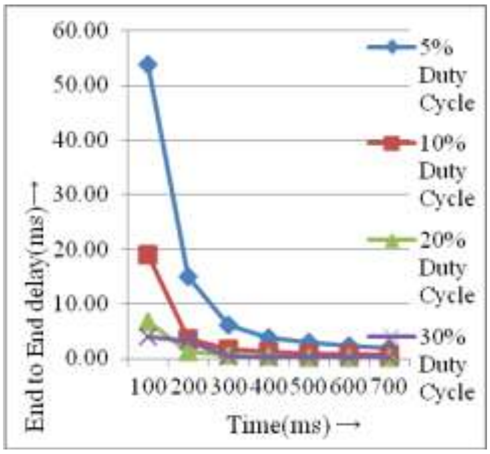

Fig. 5 Rate of end to end delay at 5%, 10% 20% and 30% duty cycles

But if consistency is considered than Figure 5 shows that 10% duty cycle is better than all remaining three duty cycles.

B. Simulation Window in NS-2

Simulation of S-MAC protocol in NS-2. When program is executed in NS-2 console using ns command the following output window is shown in figure 6. We can see that node 0 is sending data. UDP agent is attached with node 0 and node 1 is attached with null agent. The data communication between node 0 and node 1 is shown in figure.

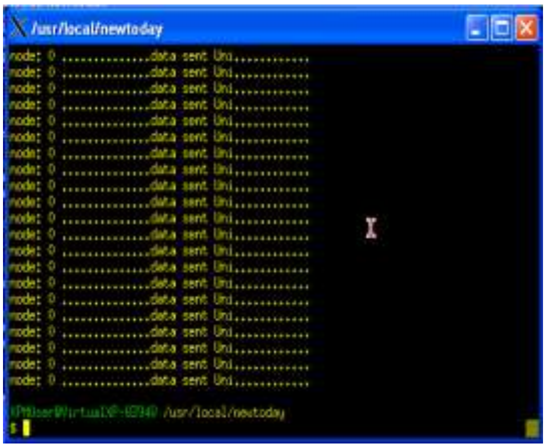

Fig. 6 Simulation Window

Simulation of S-MAC protocol in NS-2. A NAM trace file is generating during the program execution. This file is used to see graphical representation of network. For this purpose network animator is used in NS-2. The network animation window generated with NAM trace file of S-MAC program, is shown in the figure 7. The window shows that there are two nodes, node 0 and node 1 in the network represented by green color circle with node number. The black circle shows the wireless transmission of data by node 0 during network simulation.

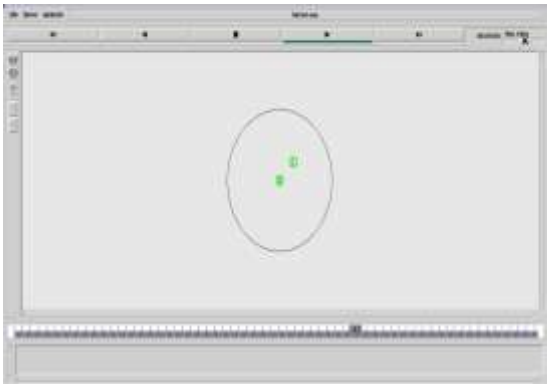

Fig. 7 Network Animator Window (2 nodes)

Simulation of S-MAC protocol in NS-2 using eight nodes in network. A NAM trace file is generating during the program execution. The NAM trace file is used to see graphical representation of network. For this purpose network animator is used in NS-2. The network animator window generated with NAM trace file of S-MAC program is shown in the figure 8.

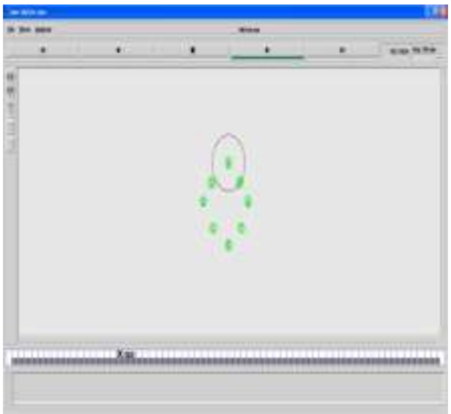

Fig. 8 Network Animator Window (8 nodes)

The window shows that there are eight nodes, node 0, node 1, node 2, node 3, node 4, node 5, node 6, node 7, and node 8 in the network represented by green color circle with node number. The black circle shows the wireless transmission of data by node 4 during network simulation.

V. CONCLUSION

Sensor Medium Access Control (S-MAC) protocol is an energy efficient protocol and it is designed for wireless sensor network and has very good energy conserving properties comparing with MAC. Another interesting property of the protocol is that it has the ability to make trade-offs between energy and latency according to traffic conditions. Energy consumption by this protocol is varying according to the variation of duty cycles. Using simulation results energy consumption is obtained and found 10% duty cycle is efficient than others. After completion the process the remaining energy in S-MAC protocol at 10% duty cycle is 805.022 joules. The consuming energy is 194.978 joules. This is 6.9469 joules more than the second better energy saving duty cycle in S-MAC protocol. Consequently, it can be seen that 10% duty cycle is efficient than other duty cycles.

This is also concluded that S-AMC is energy efficient at 10% duty cycle than MAC protocol. After completion the process the average energy remaining in MAC is 345.288 joules while in S-MAC protocol this is 805.022 joules. So S-MAC protocol save energy 459.735 joules more than MAC protocol.

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