Performance Evaluation with Energy Consumption, Cluster Throughput and Packet Delivery Ratio of S-MAC Protocol in Wireless Sensor Network

Poonam Kumari
Computer Science & Engineering Department,
Govt. Women Engineering College
Ajmer, Rajasthan, India
poonam18.saini@gmail.com

Dalpat Songara
Computer Science & Engineering Department
Govt. Women Engineering College
Ajmer, Rajasthan, India
dalpatsongara@gmail.com

Abstract-Wireless sensor network are battery operated, and hence increasing the network lifetime is one of the primary concerns. This paper introduces energy efficient Sensor-Medium Access Control (S-MAC) protocol used in sensor network. Energy consumption is the main problem in wireless sensor network. So decrease the energy consumption and increase the network lifetime of sensor nodes in sensor networks using by S-MAC protocol. S-MAC protocol uses techniques for reduce energy consumption and also support self-configuration. The first, neighboring nodes are synchronized and go to sleep periodically. Second, the synchronized neighboring nodes make a virtual cluster to synchronize their listen and sleep periods, so the control packet overhead is kept low. Third, message passing is used to decrease latency and control overhead. In present work cluster is formed then cluster head is selected, and cluster head is fixed. S-MAC protocol was simulated in NS-2. To study the performance of S-MAC in terms of network lifetime, cluster throughput, packet delivery ration, total power and energy consumption for cluster head.

Keywords: *Wireless sensor network, S-MAC protocol, Periodic listen and sleep, Cluster throughput, Packet delivery ratio, Total power and Energy consumption.*

*****

I. INTRODUCTION

Wireless sensor networks have develop into one of the research fields in recent years, as they are proposed to have wide applications with environmental monitoring, smart spaces, medical systems, robotic exploration and many other fields [1]. Modern advances in micro electro mechanical system (MEMS) technology, wireless communications, and digital electronics have enabled the development of low cost, and low battery. Sensor nodes are small in size and communicate in short distances. These sensor nodes consist of sensing, data processing, communicating components, and leverage the idea of sensor networks based on collaborative effort of a large number of nodes. Sensor networks define a significant improvement over traditional sensors, which are deployed in the following two ways [12]:

- Sensor nodes can be located distant from the actual, i.e., something known by sense awareness. Large sensor nodes are used some complex techniques. The targets form environmental noises are required.
- Several sensor nodes are present only sense. The positions of the sensor nodes and communications topology are carefully engineered.

For the WSN it is difficult to charge or replace the exhausted battery so other nodes objective is to increased sensor nodes lifetime. The characteristics of wireless channel is, if any sensor node in wireless networks sends wireless signals to other sensor nodes, these nodes receive the signal. If there are more than two sensor nodes are located in the local area network which sends the signals to the other sensor nodes and these signals may overlap. Then collision occurs, and these sensor nodes are waiting for receiving the signal but sensor nodes not received data information correctly, and sensor nodes uses more energy. Then energy consumption is increased in WSN. So, energy consumption is the main problem in WSN. To solve these types of problem and introduces energy efficient S-MAC [12].

This paper presents S-MAC, a new energy efficient MAC protocol designed explicitly for WSNs. While reducing energy consumption is the primary goal in design. S-MAC protocol and also has good scalability and collision avoidance capability.

II. THE MAIN FACTORS THAT CAUSE ENERGY CONSUMPTION IN WSN

To propose of energy efficient S-MAC protocol, some factors should be analyzed that show the way to decrement in energy consumption. During a great deal of experiments and theoretical analysis, some factors that cause the energy consumption of sensor nodes in WSN. These factors are summarized as follows:

A. Idle listening

The major source of inefficient energy sensor network is idling listening i.e., listening received possible data to the sensor nodes but not send data to the other sensor nodes. This is true in many sensor network applications. If sensor nodes not sensed, then sensor nodes will be in idle state for most of time [13]. This kind of idle listening can waste a more energy.

B. Collision

The collision occurs when two data packets are transmitted at the same time. The data packets can get corrupted, and these data packets may be required to be retransmitted. So a lot of time and energy gets wasted during this transmission and reception. Collisions should be avoided because of the extra energy wasted in retransmission of data packets [10].

C. Overhead

When sending, receiving and listening control data packet [13] then energy is needed. Because there are no transmitting data in the listening control packet. These control packets used to provide service for data information. Reduce the control message as much as possible on the basis of data information. It can be transmitted normally. S-MAC protocol should avoid and reduce the energy consumption caused.

D. Overhearing

The other problem is overhearing in which sensor nodes may received data packets from the other sensor nodes. And these sensor nodes transmitted received data packets to other sensor nodes. The sensor nodes will deal with these unnecessary data, which will make the wireless receiving and processing module, these module consume more energy [4].

III. RELATED WORK

A. S-MAC Protocol

S-MAC is a contention based MAC protocol is variation of IEEE802.11 protocol specially designed for the wireless sensor network [7].

S-MAC protocol is a clustering based protocol. S-MAC protocol decreased energy consumption in sensor networks. The key features of S-MAC protocol are:

- To protect energy by avoiding overhearing in idle listening.
- To avoid collisions and to address the hidden terminal
- To fragment of long packets divided into several frames and send in burst. [2]

S-MAC protocol assumes that the wireless sensor networks are low traffic load networks. S-MAC protocol supports a listen/sleep scheduling algorithm. In sensor network sensor nodes go to sleep period for most of the time and listen only to send data and to synchronize with other sensor nodes. Fig-1. Shows S-MAC cycle time is divided into two periods. First period is sleeping period and second period is listen period. The listen period is divided into three parts. First part is SYNC period, second part is RTS/CTS period, and third part is data transmission period. In every SYNC period, sensor nodes broadcast a SYNC packet to neighbor nodes. And sensor Nodes also use the receiving SYNC packets to synchronize with neighboring nodes in the network.

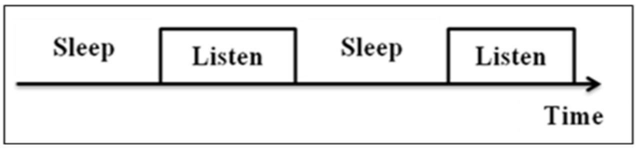

Fig-1: Periodic Listen and Sleep Cycle of S-MAC

The SYNC packets include the sender's next sleeping time. These SYNC packets tells sender's next sleeping time to receiving nodes when the next transmission would take place for the next cycle. The RTS (request to send)/CTS (clear to send) period is used to request for transmission and to response with a permission to transmit. Then, sensor nodes can send or receive data. The sleep schedule starts when sensor nodes are deployed to the workspace. Then every sensor node keeps listening to the channel for a random time period from their neighboring nodes for a SYNC packet. If a sensor node does not receive any SYNC packet at the end of the period, it will generate a sleep schedule, and then broadcast the schedule within a SYNC packet [10]. Sensor nodes receiving a SYNC packet during the listening period will use the sleep schedule attached in the SYNC packet. The sleep schedule in S-MAC can reduce the network energy consumption by introducing a low duty cycle for each node. By using the sleep schedule, S-MAC can trade off the latency with the energy saving. [5]

B. Periodic Listen and Sleep Scheduling

S-MAC adopts the mechanism which allows nodes periodically go to sleep after a certain time of listening.

In many sensor network applications, if sensor nodes receive data packets to the other sensor nodes but not sends these data packets to the sensor nodes then sensor nodes are idle for a long period of time. These sensor nodes get more energy when these are in idle state. Then large amount of energy is wasted. However, listening needs energy. In order to decrease energy consumption by idle listening, S-MAC adopts the listen and sleep scheduling mechanism. This mechanism have sleep period and listen period. In this mechanism sensor nodes periodically go to sleep period after a certain time of listening period. Each sensor nodes go to sleep for some time and then begins to listen period to the channel by a timer awaking it later. During sleep period, the sensor nodes turn off its radio, in the way, nodes can conserve some energy [9].

A complete cycle of listen and sleep period is called a frame. During listen period is normally fixed according to physical layer, MAC layer parameters, the radio bandwidth and the contention window size, while during the sleep period, in application is different from another due to the different application requirements. All sensor nodes can choose their own listen/sleep schedules. However, in S-MAC, neighboring nodes synchronize together and, to reduce control overhead. Synchronization is accomplished by periodically exchanging SYNC packets which includes the address of the sender and the time its next sleep between neighboring nodes [9]. In S-MAC, each sensor nodes maintain a schedule table for stores the schedules of all its known neighbors.

After start the working of a sensor node. In this working sensor node will generate listen period for a fixed period of time. During this time, if sensor node doesn't hear a schedule from its neighbor nodes, then it will choose its own schedule and start to follow node. This type of nodes is follower nodes. After this, the sensor node broadcasts a SYNC packet to announce the schedule. If during this fixed of time listen period the sensor node receives a schedule from a neighboring node, it will set its schedule to be the same [8]. This type of nodes is synchronizer nodes. Both of nodes not reduce the more energy consumption. The problem of energy consumption is solved using virtual cluster sensor networks, and selects the cluster head node of these virtual cluster sensor networks. This cluster head node reduces the energy consumption using parameters.

ISSN: 2321-8169
278 - 283

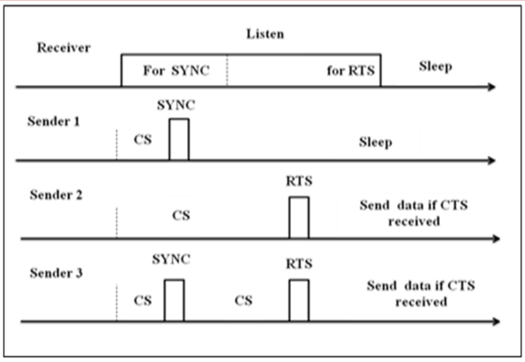

Fig-2: Timing Relationship between a Receiver and Different Senders

Fig-2. shows the timing relationship between a receiver and different senders. According this figure the sender1 send the SYNC packets to the receiver when receiver in listen period. The sender2 only send the RTS packets to the receiver and sender3 send the SYNC packets and RTS packets to the receiver.

IV. SIMULATION SETUP

To evaluate the performance of S-MAC protocol, different parameters were set in the network simulator NS-2. It has the capability to simulate both wired and wireless environment.

A. Simulation Parameters

We have used terminal having configuration: Operating system Windows XP, Pentium IV processor, 512 RAM. We use NS-2.29 and cygwin for simulation and AODV routing protocol. We take 16 sensor nodes for creating wireless sensor network, and two ray ground signal propagation model. MAC type is 802.11 MAC layer. We use network interface type is wireless phy and channel type is wireless channel.

V. SIMULATION RESULTS

In simulation we construct the sensor network contains 16 nodes. The simulation area is 670 m x 670 m. The position of sensor nodes in sensor network is defined in (x, y) coordinates. In Fig-3. shows the position of sensor nodes at time 0.2940.

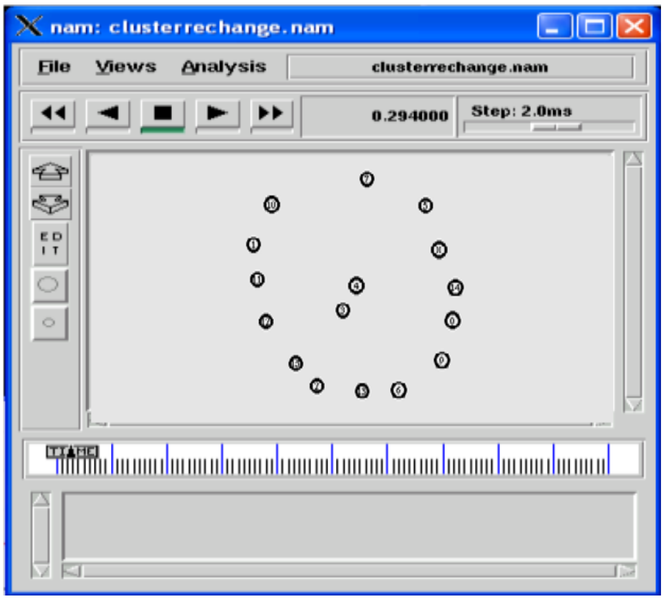

Fig-3: Movement of Nodes at Time = 0.2940

According S-MAC protocol we select a cluster head node from this creating sensor network. From this sensor network we choose sensor node 4 as a cluster head because this node shows better result according to the high level of energy. All sensor nodes transfer the packets to all neighboring node and cluster head node. In sensor network all sensor nodes are place at a single position. Data transferring is shown by colored circles. Nodes are connected to other nodes at different time intervals. Fig-4. shows the working of every node on network animator at time 1.2814.

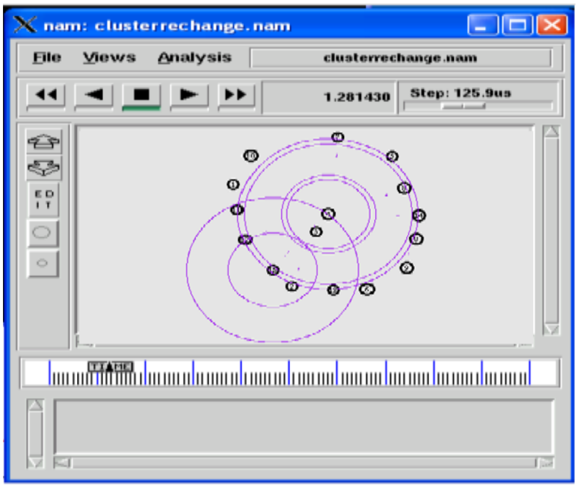

Fig-4: Working of Nodes at Time = 1.2814

VI. PROCESSING RESULTS

As time increases the processing results shows the value of packet delivery ratio, energy consumed, and number of packets received by cluster head. Processing results shows increment in cluster throughput, and packet delivery ratio. And results also show the decrement in energy consumption. Fig-5, shows the running process when packet delivery ratio is 63.

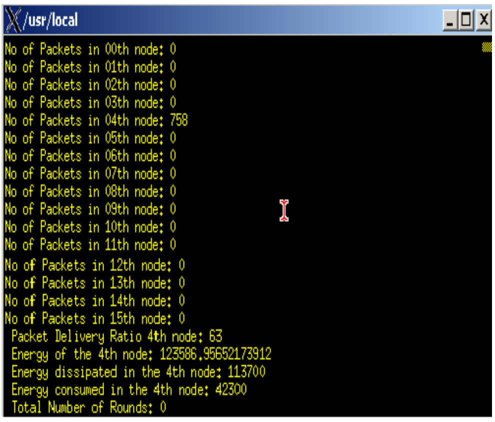

Fig-5: Running Process When PDR = 63

Fig-6. shows the running process when packet delivery ratio is 81.

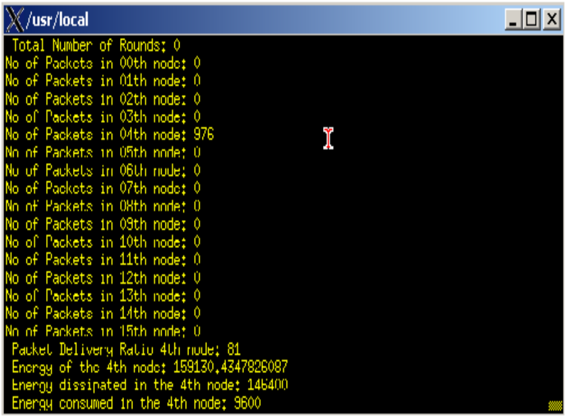

Fig-6: Running Process When PDR = 81

VII. RESULTS

A. Cluster Throughput

Cluster throughput is defined as the numbers of data packets are received successfully by the cluster head node in cluster at given time period. The greater value of received packets means better performance.

$$\text{Throughput of cluster head} = \text{Numbers of packets received by cluster head}$$

Fig-7. shows the results of cluster throughput or numbers of packets are received by cluster head with respect to simulation time. We take total numbers of sensor node 16 and initial energy is 150 joules. Shown in figure that as the simulation time is increased then numbers of received packets also increase.

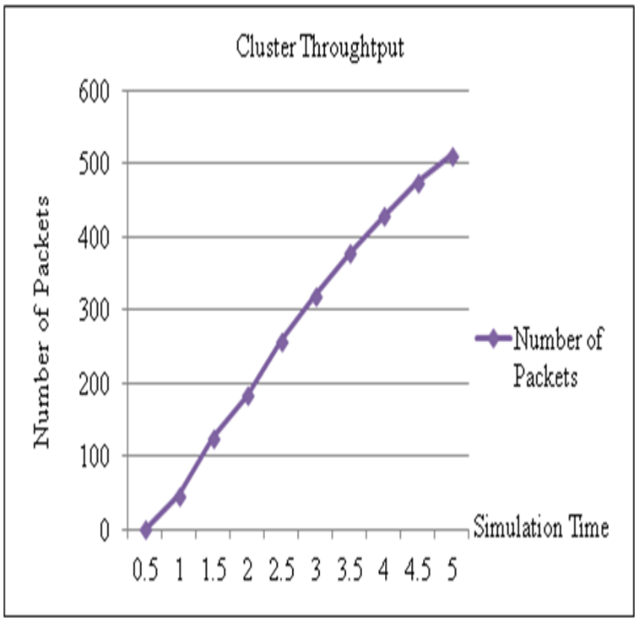

Fig-7: Number of Packets Received Vs Simulation Time

At simulation time 1 mile seconds, numbers of received packets by cluster head are 47. When simulation time is 3.5 mille seconds, then cluster throughput is 377 packets. Similarly graph shows the cluster throughput with respect to the simulation time. Here the graph shows the linear line with respect to simulation time and numbers of received packets are increased. When cluster throughput is increased then energy consumption is decreased.

B. Packet Delivery Ratio

The packet delivery ratio is the numbers of packets are received by cluster head to the size of packets of TCP

$$\text{Packet Delivery Ratio of cluster head node} = \frac{\text{Numbers of packets received by cluster head node}}{\text{TCP packet size}}$$

Fig-8. shows the results of packet delivery ratio, packet delivery with respect to the simulation time. This figure shows the when the simulation time is increased, and then packet delivery also increased.

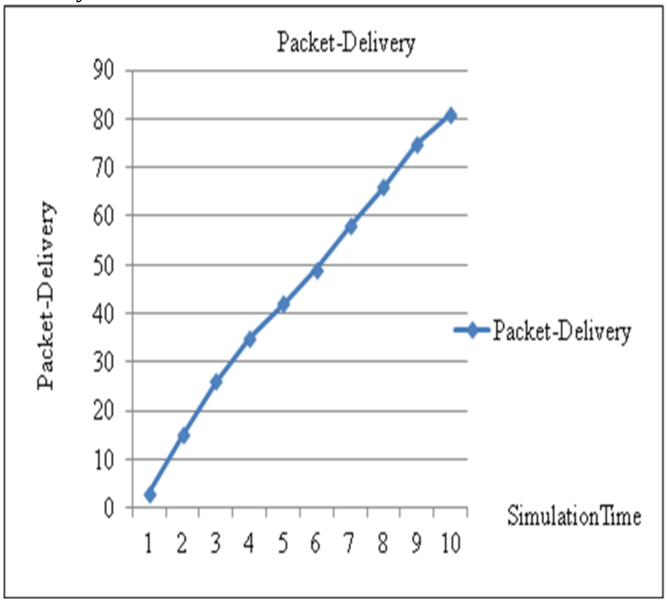

Fig-8: Packet Delivery Vs Simulation Time

At simulation time 1.0 mile seconds, delivered packets are 3. Similarly after 2 mile seconds of simulation time, packets delivered are 26. Here graph shows the linear line with respect to simulation time and packet delivery. When the numbers of packets delivery are increased, then energy consumption is decreased.

C. Total Power

The total power is increased because sensor nodes are low battery power devices in sensor network. The greater value of total power means better performance.

$$\text{Total Power of cluster head node} = \frac{\text{Number of packets received by cluster head node} * \text{Initial energy}}{.92}$$

Fig-9. shows the results of total power of cluster head with respect to the simulation time. If simulation time is increased then total power of cluster head is also increased. There are total numbers of node 16 and the amount of energy used is 150 joules. It is shown in graph that if simulation time is increased then total power is also increased. Initially when energy is zero, total power lies at constant state for some few seconds.

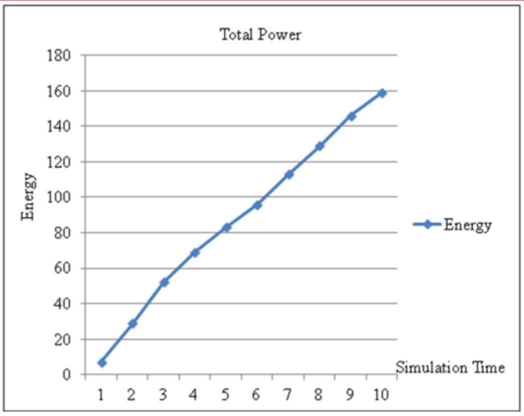

Fig-9: Total Energy Vs Simulation Time

Here graph shows the linear line with respect to simulation time and total energy. When the numbers of received packet are increased and total energy also increased, then energy consumption is decreased.

D. Energy Consumption

Energy consumed by cluster head in creating wireless sensor network. This consumed energy is defined by cluster head node.

$$\text{Energy Consumed by cluster head node} = (\text{TCP packet size} - \text{Number of packets received by cluster head node}) * \text{Initial Energy}$$

Fig-10. shows the energy consumed by cluster head node with respect to the simulation time. The results show if simulation time is increased, then energy consumed by cluster head is decreased because all sensor nodes are not in active mode at the same time, only sensor nodes which sends the data and nodes which receive the data are in active mode, rest of the other nodes are in sleep mode. When sensor nodes are in sleep mode, then sensor nodes are not used their energy and this leads to decrement in energy consumption.

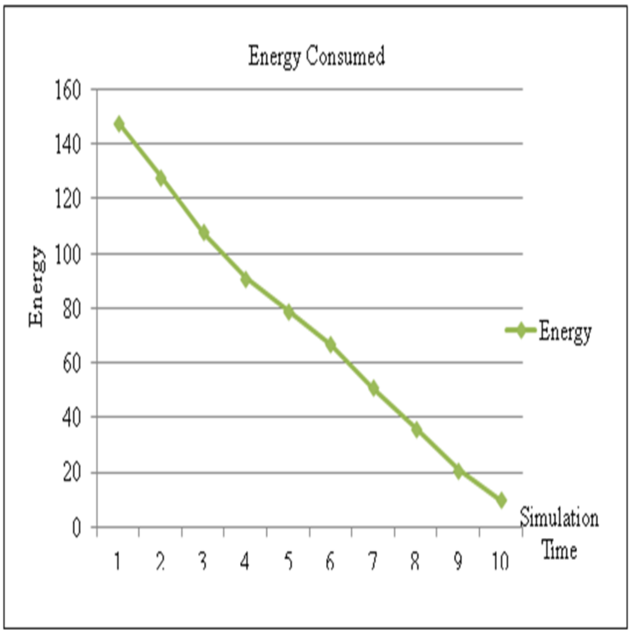

Fig-10: Energy Consumption Vs Simulation Time

Energy consumption is decreased by cluster head node with respect to simulation time, when numbers of received packets are increased on cluster head node.

It is shown at simulation time 1.0 mile second, energy consumption is 148 micro joules. At simulation time passes energy consumption is deceased, at time 3.5 mile seconds, energy consumption is 99 micro joules.

Here graph shows the linear line with respect to simulation time and energy consumed. The results of energy consumed shows, when numbers of received packets by cluster head are increased at given time, then energy consumption is decreased.

VIII. CONCLUSION

In this paper the effect of cluster head formation simulated by S-MAC protocol. In this work energy consumption, total power, cluster throughput, and packet delivery ration is implemented.

It is proved that energy consumption is reduced and also increase the network lifetime of the wireless sensor network. It also increases the total power, packet delivery ratio, and cluster throughput. It is shown that the S-MAC protocol using sleep scheduling algorithm offers a better solution to energy efficiency usage in a wireless sensor network.

REFERENCES

[1] Simarpreet Kaur and Leena Mahajan, "Power saving MAC Protocols for WSNs and Optimization of S-MAC Protocol" International Journal of Radio Frequency Identification and Wireless Sensor Networks, June 2011, Vol. 1, No. 1, pp. 1-8.

[2] Robert Abo and Kamel Barkaoui, Karim Djouani, "Verification and Performance Evaluation of S-MAC Protocol Based on Process Calculi", 30th International Conference on Distributed Computing Systems Workshops (ICDCSW-2010), IEEE , pp. 189 - 198 , 21-25 June 2010, ISSN : 1545-0678, Genova.

[3] "NS2 for Begginers", Eitan Altman and Tania Jimenez, University Le de Los Andes,Merida

[4] Urmila A. Patil, Smita V. Modi, Suma B. J., "A Survey: MAC Layer Protocol for Wireless Sensor Networks" International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 9, September 2013, pp.

[5] Yujun Pang, "A New Optimization Strategy for S-MAC Protocol", International Conference on Computer Application and System Modeling (ICCASM- 2010), Vol. 14, pp. 328-331, 22-24 Oct 2010, ISBN: 978-1-4244-7235-2, Taiyuan.

[6] Wei Ye, John Heidemann, Deborah Estrin, "An Energy-Efficient MAC Protocol for Wireless Sensor Networks," Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies, (INFOCOM-2002), Proceedings, IEEE, Vol.3, Pp.1567–1576, 2002. ISBN: 0-7803-7476-2.

[7] Salman Faiz Solehria, Sultanullah Jadoon,Medium Access Control Protocol for Wireless Sensor Network – a Survey", International Journal of Video & Image Processing and Network Security IJVIPNS-IJENS, June 2011, Vol: 11, No: 03, pp. 14- 18.

[8] SONG Wen-miao, LIU Yan-ming, ZHANG Shu-e, "Research on SMAC Protocol for WSN", Wireless Communications, 4th International Conference on Networking and Mobile Computing, (WiCOM-08), pp. 1-4, 12-14 Oct 2008..

[9] Ye, W., J. Heidemann, and D. Estrin, "Medium Access Control with Coordinated adaptive Sleeping for Wireless Sensor Networks", IEEE/ACM Transaction on Network, Vol. 12, No. 3, June 2004, pp. 493-506.

[10] Sung-Chan Choi, Jang-Won Lee, Yeonsoo Kim, Hakjin Chong, "An Energy-Efficient Mac Protocol with Random Listen-Sleep Schedule for Wireless Sensor Networks", IEEE Region 10 Conference (TENCON-2007), pp.1-4, 30 Oct.-2 Nov. 2007, ISBN: 978-1-4244-1272-3.

[11] http://www.Tcl.tk/nam/tcl8.5/tutorial/tcltutorial.html

[12] I.F. Akyildiz, W. Su, Y.Sankarasubramaniam and E. Cayirci, "Wireless sensor networks:a survey", Elsevier Science B.V., pp. 393-422, 2002.

[13] IIker Demirkol, Cem Ersoy, and Fatih Alagöz, "MAC Protocols for Wireless Sensor Networks: A Survey", IEEE Communication Magazine, pp. 115-121, April 2006, ISSN: 0163-6804.

BIOGRAPHIES

Ms. Poonam Kumari is pursuing M.Tech in CSE from Govt. Women Engineering College Ajmer. She has completed her B.Tech in 2013 from LIET, Alwar, India.

Mr. Dalpat Songara is an Assistant Professor in Dept. of Computer Engineering in Govt. Women Engineering College Ajmer, Rajasthan, India. He has done his M.Tech in CSE from India. His research interests lies in Wireless Sensor Network and Algorithm.