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Performance Analysis on Energy Aware MAC protocol for Wireless Sensor Network

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Abstract. Wireless Sensor Network has been widely used in variety of fields. However, the energy problem has been a challenge in practical applications for WSN. The radio transmission consumes lots of energy in WSN as compare to other subsystems. The MAC protocol controls the radio transmission. Medium Access Control has a significant effect on the energy consumption. In the performance evaluation of a protocol for wireless sensor network, the protocol should be tested under realistic conditions for representative data traffic models. Several techniques are available that described an energy-efficient S-MAC protocol, which is a well-known MAC protocol for WSN. The others protocols remove the defects of S-MAC. The major problem with different MAC protocols is they itself consume lots of energy while accessing channel, overhearing, and collision. Some methods reduce this by using different technology but at the cost of increased latency. The basic problem of energy utilization is ignored in the existing protocols. Each node utilizes same amount of transmission power irrespective of the distance from destination node. To solve problem and distance issue, some new research on MAC protocol is required. The ES-MAC protocol gives the enhancement to basic S-MAC protocol and removes the drawback of current S-Mac protocol.

Keywords: AS-MAC; energy efficient; ES-MAC; sensor; protocol.

1. Introduction

A sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. The environment can be the physical world, a biological system, or an information technology (IT) framework. Communication networks, especially wireless, eliminate barriers of distance and time. Future modern society will see a growing reliance on and need for powerful sensor networks with high flexibility, performance and functionality with low power consumptions. As sensor is consists of various computing subsystems like processor, memory, ADC and transceiver, which consume lots of energy. If one node failed due to exhausted battery, the network may collapse. The radio transmission subsystem is major energy consumer in WSN as compared to other [1].

1.1 Factors that cause energy consumption

To design an energy-efficient MAC protocol, it is necessary to analyze the factors those lead to energy consumption [2].

Idle listening: Energy wasted when radio is in idle state especially in WSN with low rate of data. RF module has to be in the receiving state so as to receive the packets.

Collision: In the situation of sharing the wireless channel in competitive mode, when two packets are transmitted at the same time, collision occurs and the packets have to be re-transmitted subsequently. As we know, transmitting data needs more energy.

Overhearing: When a node receives a packet that is addressed to some other node, the node will deal with this unnecessary data, this increases energy consumption [3].

So, the above said factors waste the energy in communication. All communication is handled by the MAC protocol in WSN. Hence, good MAC protocol saves lots of energy.

1.2 Mac selection criteria

As stated above, sensor nodes are likely to be battery powered. Some nodes may die over time; some new nodes may join later; some nodes may move to different locations. A good MAC protocol should easily accommodate such network changes [2] [4]. At the time of choosing a MAC protocol some attributes must be considered like scalability, collision avoidance, energy efficiency, channel utilization, latency and fairness. So many MAC protocols are available in different classes. The main two classes are random access and scheduled access. In the scheduled access, fixed time slots are allocated for every node to acquire channel. The random access is suitable for WSN and all nodes have to compete for the channel. Synchronous and asynchronous modes are subtypes of random access. Further MAC protocol is selected according to application. Sensor MAC is very popular and described below.

2. Related work and their problems

2.1 Sensor MAC

"SCADDS" group at USC/ISI proposed S-MAC which is an energy-efficient protocol especially designed for WSN and implemented on IEEE 802.11 [5]. It has a periodic listen –sleep schedule, adaptive listening, and crosstalk avoidance scheme as shown in fig 1.

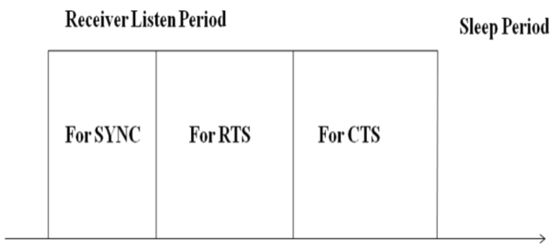

Figure 1. Sensor MAC protocol cycle (Courtesy: J. Heidemann, et al., 2002)

As idle mode of radio consumes lots of energy, switching off the radio when not in use is beneficial. S-MAC controls this by periodic listen-sleep schedule of nodes as shown in figure1. This also increases the latency if during transmission sensor goes into sleep mode because of extended transmission even after allotted fixed slot. So, new protocol is required which has to be based on dynamic sleep schedule as per transmission requirement.

2.2 Adaptive listen sleep MAC

The advance MAC protocol is a variant of basic S-MAC protocol. This scheme has three different modes of sleep which are very dynamic as shown in figure 2. It reduces the energy consumption and latency too. But the basic problem of energy consumption at the node in transmission is still ignored. Due to three dynamic sleep modes, it can adjust the transmission to avoid latency where Ts1 > Ts2 > Ts3. (Ts- Sleep Time) [6].

2.3 Problems in the existing solution

The above discussed methods are mainly based on S-MAC with different sleep a mechanism which reduces energy consumption and has a good scalability. But the existences of the following two problems from the current study [7].

- All the nodes use the default transmission power to send out data packet irrespective of energy level and ignore the distance between nodes, which result in wastage of limited energy.
- The S-MAC agreement adopts the default competition window and lacks in providing protection to the energy exhausted nodes, which would affect the performance of the entire network.

Along with the operation of the network, available energies of node may be less than other nodes. For instance, the nodes near the Sink need transmit data packets towards sink frequently. As channel access requires lots of energy, the less energy node can't retry frequently and hence failed to achieve transmission. The Competition window distribution mechanism of S-MAC is shown in Fig. 3 and Eq.1.[7].

Here, CW -- Competition window within sync period.

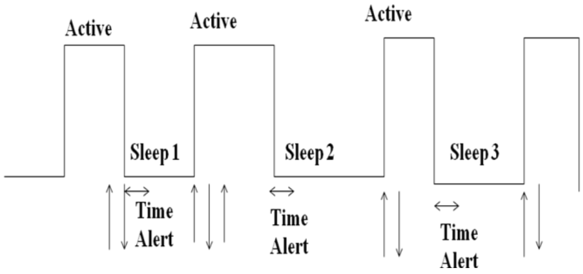

Figure 2. AS-MAC protocol mechanism for dynamic sleep(coutesy: Qingchun Yu,et al., 2006).

In the figure 3, contention window is very large. As the time of competition window increases, the collision increases. It decreases the performance and increases power consumption.

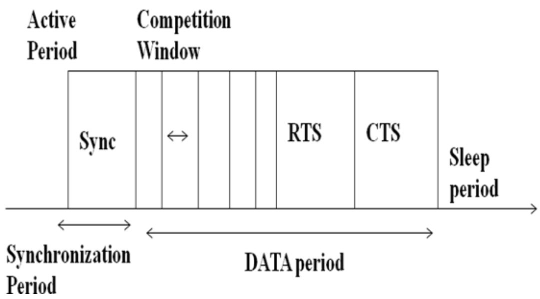

Figure 3. Competition window distribution mechanism of S-MAC (Courtesy: Changbiao Xu, et al., 2008)

Listen time = Random (0, DATA_CW)*Slot time (1)

3. Enhanced MAC Protocol.

According to this, energy gets saved rather than using default power for transmission. It can estimate distances between two nodes according to received power. When knowing two nodes separated by a distance d, the transmitting power can be adjusted so that the distance of d just receives the power of packet nodes and transmit, rather than using fixed transmission power to achieve purpose of saving energy. Supposing that we know sending power to all nodes, following mechanism is used in order to adjust S-MAC transmitter power [7]. These two mechanisms are explained below.

3.1 Transmission power Utilization as per distance

When the network begins initialization, there is no record of the distance between nodes; all nodes use the default power to send data packets. When a node receives a uni-cast packet correctly, it will read the ID information of packet's head, checking whether there is node position record. If not, it can calculate distance of the node based on receiving energy in transmission method and transmit node ID and record the distance between two nodes. If not found it calculates the distance by using the free path loss mechanism [7] in which emission power can be calculated by distance. So, if the distance is unknown then it is calculated by energy received at receiver side and makes the entry in distance table. This method uses two-ray ground reflection model to determine transmission energy. A single line-of-sight path between two mobile nodes is seldom the only means of propagation. The two-ray ground reflection model considers both the direct path and a ground reflection path. It is shown that this model gives more accurate prediction at a long distance than the free space model. It assumes that no obstacle in between path. Then the received energy is at distance'd' between two nodes can be calculated as

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

As Pt and Pr known, the distance between two nodes can be calculated as below.

$$d = \sqrt[4]{\frac{P_t G_t G_r h_t^2 h_r^2}{P_r L}} \quad (3)$$

The following table shows all parameter list which used in equations. When the distance between two nodes is known, it confirms minimum transmitting power Pt according to the RX-Thresh:

TABLE I Parameter list of ES-MAC

Parameters	Description
D	Distance between sender and receiver
Pt	Signal transmission power
Gt	Sender antenna gain
Gr	Receiver antenna gain
L	Propagation Loss
Ht	Antenna height of sender
Hr	Antenna height of receiver
CW	Competition window

$$P_{t(d)} = \frac{RX\_ThreshG_t G_r h_t^2 h_r^2}{d^4 L} \quad (4)$$

After above conversion, the smallest transmitting power can be obtained through the propagation model.

3.2 Protection to the less energies Nodes

In the ES-MAC protocol also protects the node by setting high priority to the nodes near to sink. So the nodes get secured and increase the lifetime of node. It sets the minimum threshold and when the energy of the node goes below this threshold, the node will use smaller data competition window to improve the probabilities of access channel nodes and reduce unnecessary carrier sensing time. Thus energy efficiency of nodes is increased. The reason is, when the energy of the node is lower and can’t be obtained by sending packets, when energy of all nodes are below the threshold and the competition window is too small, it will lead to conflict between the nodes easily and increases energy consumption of nodes. In this method half acquiescence competition window S-MAC (64 slot) is used (32 slots) as shown in Eq. 5.

Listen time = Random (0, DATA_CW/2)* slot-time (5)

3.3 Support of Different Access Priorities

Carrier sense time before the node obtains channel is a random selection of numerical in the competition window value. Obviously, the node given smaller competitive window has a larger priority of access channel. This paper defines three different nodes: High, medium and low priority. Low priority still uses the default S-MAC competition window which has 64 slot value, medium priority has 64/2 slot value which means 32 and High-priority has 16 slot value. Carrier sense time before the node obtains channel is a random selection of numerical in the competition window value. Obviously, the node given smaller competitive window has a larger priority of accessing channel. Thus the method will reduce the default power and nodes get secured in the competition. This may reduce the energy consumption.

4. Experimental Setup and results

The above said protocols are simulated with NS-2.29 on Linux enterprise. We have tested performance for energy consumption using various parameters. Combination of topologies like random, star and linear is used with routing protocols like DumbAgent, DSR by varying number of nodes. The results of experiments are shown in graphs.

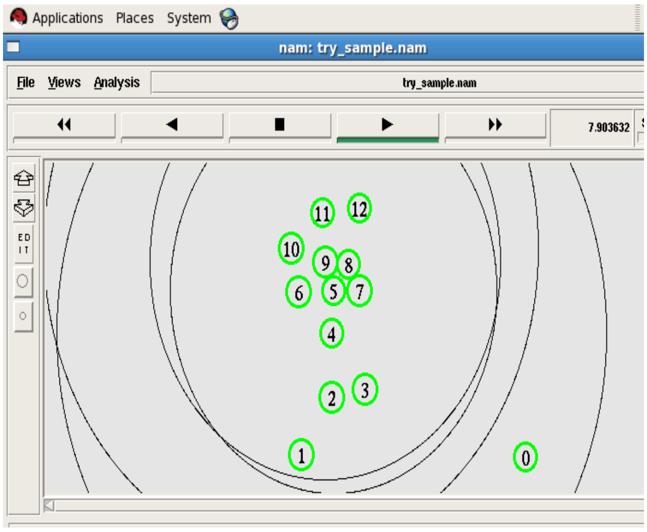

Figure 4. Data transmission scenario- 2 in ES-MAC with Random Topology

Figure 4 shows the output of Nam file. In this step shows simulation interval which is set to 2.0 ms. This screen shot is taken at middle of the simulation after 7.90 second. Here, '0' is the sink node, cluster head are 1, 2 and other are common node.

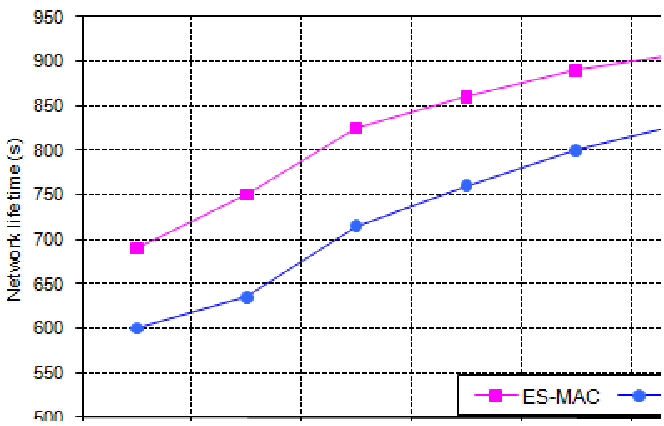

Figure 5. Compare ES-MAC and S-MAC network lifetime

From above experimental setup, figure 5 tells the comparison between ES-MAC and S-MAC network lifetime with respective message sending interval. This shows that ES-MAC network life is good than S-MAC. X-axis shows message sending interval considered in second and Y-axis shows what life of network is in seconds.

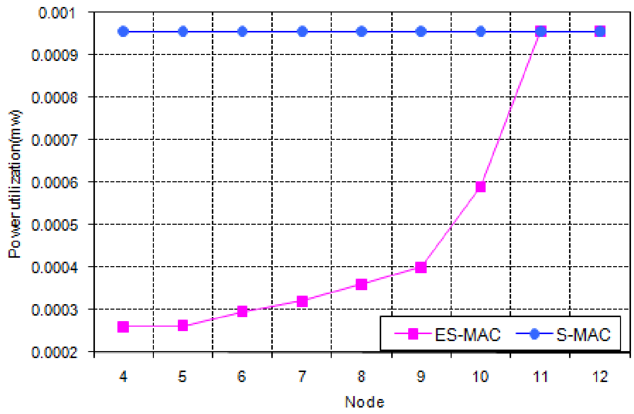

Figure 6. power utilization of s-mac and es_mac with 100% duty cycle with respective each node

The above graph shows the comparison of ES-MAC with S-MAC transmission power with respective each node i.e default power vs calculated power at the time of transmission. In the future this hybrid Energy aware Mac protocol can be developed by using combination of two different mechanisms. As per the new protocols are coming in picture the problem of energy wastage can be solved easily in future.

5. Acknowledgments

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