Effective Energy Efficiency In MAC Protocal

Amit Debnath
CSE Department
Tripura University (A Central University)
Agartala, Tripura, India
amitdebnath84@yahoo.in

Swapan Debbarma
CSE Department
NIT, Agartala
Agartala, Tripura, India
swapanxavier@gmail.com

Abstract— **Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies for the twenty-first century. WSNs employ thousands of small sensors that communicate between themselves in a distributed manner using Medium Access Control (MAC) protocols. Energy required for wireless sensor is obtained from non-rechargeable energy sources [1]. Due to their small size, wireless sensors are highly constrained in terms of battery energy. Hence, energy efficiency is considered a key factor in the design of a WSNs. MAC protocols play an important role in the successful operation of WSNs. Energy efficiency can be achieved by introducing some significant changes that effect the energy consumption at the MAC layer [2]. Existing protocols achieve energy savings, trading off either latency or throughput. Sensor Medium Access Control(S-MAC) is one such protocol that identifies a few sources of energy wastage and proposes an adaptive sleep-and-listen scheme to minimize energy wastage.**

Keywords- WSN, MAC, S-MAC, CBEE-MAC,T-MAC, LPL

I. INTRODUCTION

Wireless sensor networking is an emerging technology that has a wide range of potential applications including environmental monitoring, smart spaces, medical systems and robotic exploration. Such a network normally consists of a large number of distributed nodes that organize themselves into a multi-hop wireless network. Each node has one or more sensors, embedded processors and low-power radios, and is normally battery operated [2]. A wireless sensor network is a network made of numerous small, independent and specially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure, motion or pollutants. These small and inexpensive devices, typically the size of a 35 mm film canister and the price about several US$s, are self-contained units consisting of a battery, radio front end, sensors, and a minimal amount of on-board computing power. All these components together in a single device form a so-called sensor node Due to the small and inexpensive characteristics of sensor nodes, they can be produced and deployed in large numbers, and their resources in terms of energy, memory, computational speed and bandwidth are severely constrained. In addition, sensor nodes are often deployed in hostile environments or over large geographical areas, so the battery of a sensor node is often not rechargeable. How to reduce the energy consumption to prolong the service lifetime of sensor nodes becomes a critical issue [3]. As power consumption is one of the biggest problems of sensor networks and it is greatly affected by the communication between nodes, the communication protocols of different layers are designed with the energy conservation in mind. Medium access control (MAC) has been and still is one of the most active research areas for wireless sensor networks (as it is for ad-hoc networks).

A. Design purpose

To design a good MAC protocol for the wireless sensor networks, we have considered the following attributes. The first is the energy efficiency. As stated above sensor nodes are likely to be battery powered, and it is often very difficult to change or recharge batteries for these nodes [4]. In fact, someday we expect some nodes to be cheap enough that they are discarded rather than recharged. Prolonging network lifetime for these nodes is a critical issue. Another important attribute is the scalability to the change in network size, node density and topology. Some nodes may die over time; some new nodes may join later; some nodes may move to different locations. The network topology changes over times as well due to many reasons. A good MAC protocol should easily accommodate such network changes. Other important attributes include fairness, latency, throughput and bandwidth utilization. These attributes are generally the primary concerns in traditional wireless voice and data networks, but in sensor networks they are secondary. For these various energy efficient medium access protocols incorporating some drawbacks have been proposed [5]. Due to tbe drawbacks of these protocols tbey causes some energy inefficiency and so we have proposed the design and algorithm of an energy efficiency MAC protocol for WSNs and named it as "Cluster Based Energy Efficient Medium Access Control (CBEE-MAC)" as it is based upon clustering concepts and our design purpose is to reduce tbe energy wastage in the existing S-MAC [6].

II. WIRLESS SENCOR NETWORK

Wireless sensor network are one of the category belongs to ad-hoc networks. Sensor network are also composed of nodes. Here actually the node has a specific name that is "Sensor" because these nodes are equipped with smart sensors [8]. A sensor node is a device that converts a sensed characteristic like temperature, vibrations, pressure into a form recognize by the users. Wireless sensor networks nodes are less mobile than ad-hoc networks. So mobility in case of ad-hoc is more. In wireless sensor network data are requested depending upon certain physical quantity [9]. So the wireless sensor network is data centric. A sensor consists of a transducer, an embedded processor, small memory unit and a wireless transceiver and all these devices run on the power supplied by an attached battery

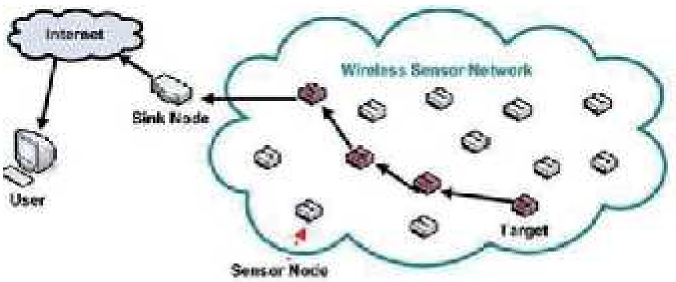


Fig 1. Wireless sensor network scenario

III. WIRELESS SENSOR PROTOCOL STACK

Wireless Sensor Network protocol as shown in Figure 2 stack consists of five protocol layers: Physical layer, Data link layer, Network layer, Transport layer, Application layer and three vertical planes: power management plane, mobility management plane and task management plane.

Power management plane manages how a sensor node uses its power. Mobility management plane is one that detects and registers the movement of nodes, keeping tracks of route back to the user and its neighbor nodes. Task management plane is one that balances and schedules sensing tasks of a specific region of nodes cooperative sensing. The application layer contains a variety of application layer protocols to generate various sensor network applications [12]. The transport layer is responsible for reliable data delivery required by the application layer. The network layer is responsible for routing the data from the transport layer. The data link layer is primarily responsible for data stream multiplexing, data frame transmission and reception, medium access, and error control. The physical layer is responsible for signal transmission and reception over a physical communication medium, including frequency generation, signal modulation, transmission and reception, data encryption, and so on. We are considering the data link layer for our performance evaluation because the Medium Access Control (MAC) sub layer is a part of it.

IV. MEDIUM ACCESS CONTROL (MAC) LAYER

The media access control (MAC) data communication protocol sub-layer, also known as the medium access control, is a sub layer of the data link layer specified in the seven-layer OSI model (layer 2) [7]. It provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium, e.g. Ethernet. The hardware that implements the MAC is referred to as a medium access controller [10]. The MAC sub-layer acts as an interface between the logical Link control (LLC) sub layer and the network's physical layer. The MAC layer emulates a full-duplex logical communication channel in a multi-point network. This cannel may provide unicast, multicast or broadcast communication service.

V. ENERGY MODEL IN MAC LAYER OFWSNS

Energy model is a node attribute which represents level of energy in a mobile host. The energy model only maintains the total energy and does not maintain radio states. Radio on a sensor node uses most energy. Not only transmitting costs energy; receiving, or merely scanning the ether for communication, can use up to half as much, depending on the type of radio [11]. Initial Energy in the energy model of a node is defined as the level of energy the node has at beginning of the simulation. It has an initial value which is known as *initial Energy.*

VI. ENERGY ANALYSIS THROUGH TRACE FILES

To help analyzing energy consumption in different states they enhanced the energy trace on individual state: sleep, idle, transmit, and receive. In addition to the total energy, now users will be able to see the energy consumption in different states at a given time.
Following is an example from a trace file on energy.

[Energy 979.917000 Ei 20.074 Es 0.000 et 0.003 Er 0.006]

The meaning of each item is as follows Energy: total remaining energy

Ei: energy consumption in IDLE state

Es: energy consumption in SLEEP state.

Et: energy consumed in transmitting packets.

Er: energy consumed in receiving packets:

VII. ENERGY WASTE IN MAC PROTOCOL

The major sources of energy waste in a MAC protocol for wireless sensor networks are the following:
Collision: When a transmitted packet is corrupted it has to be discarded, and the follow-on retransmissions increase energy consumption.
Control Packet Overhead: Sending and receiving control packets consumes energy too, and less useful data packets can be transmitted.

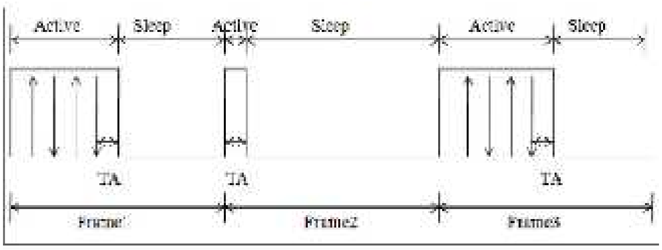
Idle Listening: Listening to receive possible traffic that is not sent can consume extra energy [13].

Overhearing: A node picks up packets that are destined to other nodes can unnecessarily consume energy.

Traditional wakeup scheduling approach like S-MAC uses fixed duty cycle. Duty Cycle is defined as Listen Interval divided by Frame Length. S-MAC and TMAC use coordinated scheduling to reduce energy consumption, but require periodic synchronization, but CMAC avoids synchronization overhead while supporting low latency. CMAC uses unsynchronized sleep scheduling and allows operation at very low duty cycles. TMAC has advantage of dynamically ending active part, it uses adaptive duty cycle. This reduces energy wasted on idle listening.

VIII. TIMEOUT MAC (TMAC)

In S-MAC [1]. When there is no traffic in the nodes they stay awaken needlessly long time. Therefore. a solution is to prematurely go back to sleep mode when no traffic has happened for a certain time (equal to timeout). In TMAC nodes transmit all messages in bursts of variable length and sleep between bursts. It uses RTS-CTS- ACK scheme and synchronization is done similar to S-MAC. A Node keeps listening and transmitting as long as it is in an active period else it sleeps. A node is in active mode until no activation event occurs for timeout period TA [14]. TMAC improves on S-MAC by shortening the awaken period when it is IDLE. TMAC has an adaptive duty cycle. Active time is dynamically adjusted by timeout on hearing nothing during time period (TA). TMAC suffers from an early sleeping problem (a node goes to sleep when a neighbor still has messages for it) due to the asymmetric communication, but it overcomes the problem using FRTS (Future-Request-To-Send). After overhearing CTS, a node quickly sends a FRTS. One of the reasons for the early sleeping problem is that the synchronization of the listen periods within virtual clusters is broken



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IX. LPL

In the protocols like S-MAC and TMAC periodic sleeping is supported by some means to synchronize wake up of nodes to ensure meeting between sender and receiver. Low Power Listening (LPL) protocol does not try to explicitly synchronize the nodes. These protocols allow the receiver to sleep most of the time and only periodically sample the channel. Senders use long preambles to ensure that receiver stays awake to catch actual packet. Figure 2 shows preamble sampling in LPL.

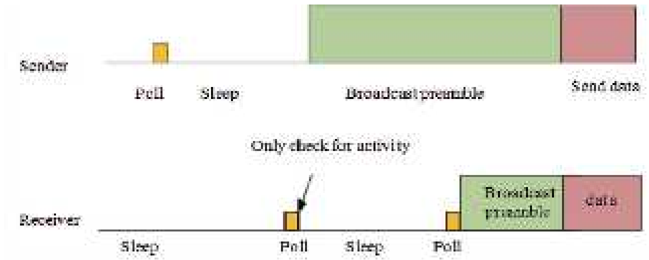


Fig 2. Preamble sampling in low power listening

X. BERKELEY-MAC (BMAC)

BMAC [14] is a carrier sense media access protocol for wireless sensor networks that combines CSMA and Low Power Listening technique. And achieve low power consumption. BMAC uses unsynchronized duty cycling and uses long preambles to wake up receivers. In BMAC a filter Mechanism is defined that increase the reliability of channel assessment. It provides a flexibility interface which allows the sensor node to change any operating variables in the protocol, B-MAC duty cycles the radio through periodic channel sampling that are called Low Power Listening (LPL). B-MAC uses the clear channel assessment (CCA) techniques to decide whether there is a packet arriving when node wakes up. Timeout puts node back to sleep if no packet arrived [15]. BMAC uses CCA and packet bakeoffs for channel arbitration, link layer acknowledgments for reliability. B-MAC does not have synchronization, RTS, CTS.

XI. WISE-MAC

In Wise MAC a sender starts the preamble before the receiver is expected to wake up rather than selecting a random time. In Wise MAC a preamble precedes each data packet for alerting the receiving node. All nodes in a network sample the medium with a common period, but their relative schedule offsets are independent. If a node finds the medium busy after it wakes up and samples the medium, it continues to listen until it receives a data packet or the medium becomes idle again. The size of the preamble is initially set to be equal to the sampling period. Figure 8 shows preamble minimization in Wise MAC. The nodes learn and refresh their neighbors sleep schedule during every data exchange as part of the Acknowledgment message. Every node keeps a table of the sleep schedules of its neighbors and decides own schedule accordingly. To decrease the possibility of collisions caused by that specific start time of a wake-up preamble, a random wake-up preamble can be adopted. The clock drifts between the source and the destination affects the wake-up preamble length.

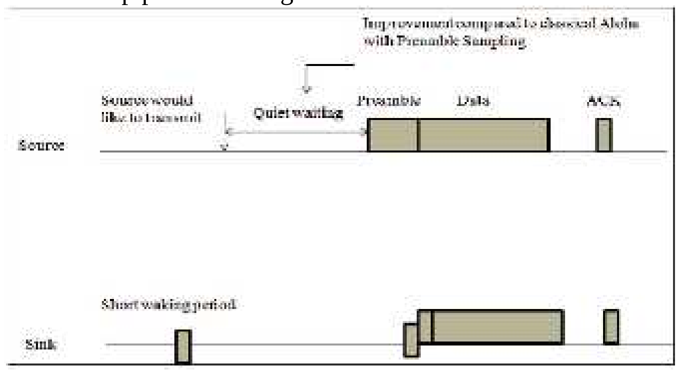


Fig 3. Wise MAC preamble minimization

XII. SMAC(SENSOR-MAC PROTOCOL)

S-MAC stands for Sensor-MAC, is a medium access control (MAC) protocol designed to achieve energy efficiency in wireless sensor networks (WSN). The energy efficiency in S-MAC is achieved by introducing low duty cycle operation. S-MAC attempts to address the following aspects in wireless sensor networks.

The periodic sleep and listen is the most important feature of S-MAC protocol. In order for nodes operating on S-MAC to follow the same sleep-wake up pattern, synchronization between nodes is needed. S-MAC defines a complete synchronization including periodic SYNC packets broadcast, schedule neighbor list and neighbor discovery to maximize energy savings and put synchronization in place.

Overhearing is another source of energy waste, especially when the node density is high and traffic load is heavy in the network.

In shared-medium networks, one of the major concerns is to avoid collisions between nodes. In this aspect, S-MAC is quite similar with the IEEE 802.11 Distributed Coordinated Function (DCF) protocol standard. The features that S-MAC has adopted include physical and virtual carrier sense, RTS/CTSIDATAIACK sequence for hidden terminal problem [16].

XIII. PERIODIC LISTEN & SLEEP

The periodic sleep counts for a major share in the energy savings achieved in S-MAC. The basic idea is to let each node follow a periodic sleep and listen schedule, as shown in Figure 4 In listen period, the node wakes up for performing listening and communicating with other nodes. When sleep period comes, the nodes will try to sleep by turning off their radios. In this way, the time spent on idle listening can be significantly reduced, which accordingly saves a lot of energy, especially when traffic load is low. 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. A complete cycle of listen and sleep period is called a frame. During listen period, the node may start sending or receiving packets if necessary. S-MAC provides a controllable parameter duty cycle, whose value is the ratio of the listen period to the frame length. In fact, the listen period is normally fixed according to some physical and MAC layer parameters.

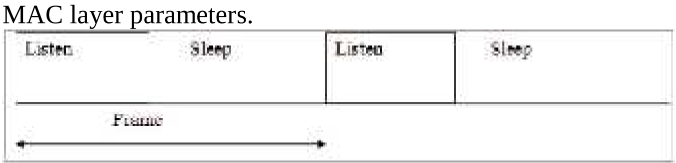


Fig 4. Sleep & listen in S-MAC

The listen period is further divided into two parts. The first one called SYNC period is designed for SYNC packets, which are broadcast packets and used to solve synchronization problems between neighboring nodes. The second one called DATA period is designed for transmitting DATA packets. The following Figure 5 shows the SYNC and the DATA times in S-MAC protocol.

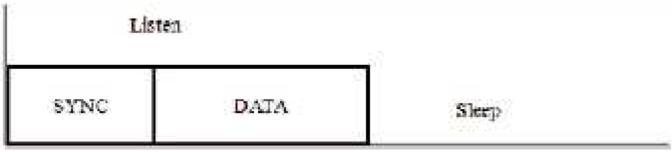


Fig 5. Listen time in S-MAC

XIV. OVERHEARING AVOIDANCE

For contention-based protocols like IEEE 802.11, overhearing is one of the major sources of energy waste. Overhearing takes place on a node when it receives some packets that are destined for other nodes. In IEEE 802.11, measures like latency and bandwidth utilization are considered in the first place. To achieve better performance in a shared-medium network, carrier sense, especially virtual carrier sense should be performed more efficiently. The best way to achieve it is to let each node keep listening to all its neighbors' transmissions. Obviously, this method will lead to large amounts of energy consumptions on overhearing, especially when node density is high and the traffic load in the network is heavy.

For S-MAC, saving energy is its primary goal. To avoid overhearing. S-MAC forces interfering nodes to go to sleep after they receive an RTS or a CTS packet that is not destined for them. In this way. Nodes that interfere their neighbor's transmissions will not hear DATA packets [17]. Which normally take much longer transmission time than control packets, and following ACK packets? We take an example in Figure 6 to illustrate this algorithm.

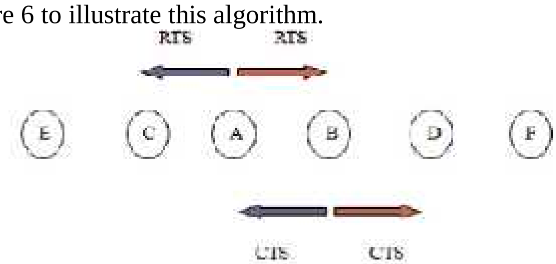


Fig 6. C and D overhears the transmission between A and B

XV. CBEE-MAC

This chapter discusses the design of our newly proposed protocol named as "Cluster Based Energy Efficient Medium Access Control (CBEE-MAC)" protocol, This protocol is designed considering the existing S-MAC protocol as the base and by adding certain features in S-MAC. This chapter also compares CBEE-MAC with the existing S-MAC in various aspects and tries to prove that CBEE-MAC outperforms the existing S-MAC by overcoming the difficulties existing in S-MAC protocol.

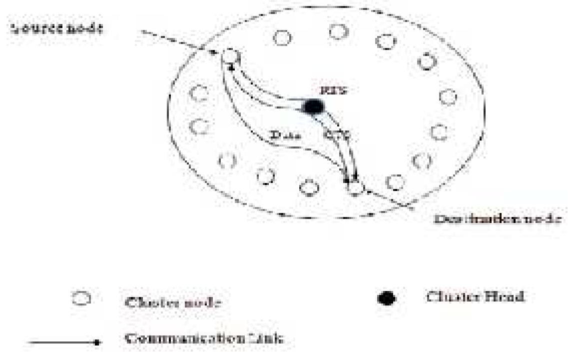


Fig 7. Intra-Cluster CBEE-MAC

Inter-cluster CBEE-MAC: In inter-cluster CBEE-MAC as shown in Figure 7 the sender and the receiver nodes are residing in two different clusters and the communication between sender and receiver is via cluster head (two or more cluster heads and gateway). Among the various border nodes, only one node can act as gateway at a particular time for particular task. Moreover gateway can handle one particular task at a time. First the transmission and reception of various control packets between sender and receiver wiU be via cluster head as follows: the cluster head- gateway-cluster head and then the transmission of data will be via gateway as follows: sender- gateway-receiver and the reception of ACK will be as follows: receiver-ACtc-sender.

XVI. Duty cycle consumption in CBEE-MAC and S-MAC

The sleep, listen, cycle times are calculated using the following expressions:

I. Listen time =(sleeptime-datatime)
2. Cycle time =(Listentime -Dutycycle)
3. Sleep time=(Cycle time-Listen time)

By looking at Figure 8 we can say that the duty cycle is directly proportional to the listen time and as listen time is reduced in case of CBEE-MAC so duty cycle of CBEE-MAC is less than the duty cycle of S-MAC.

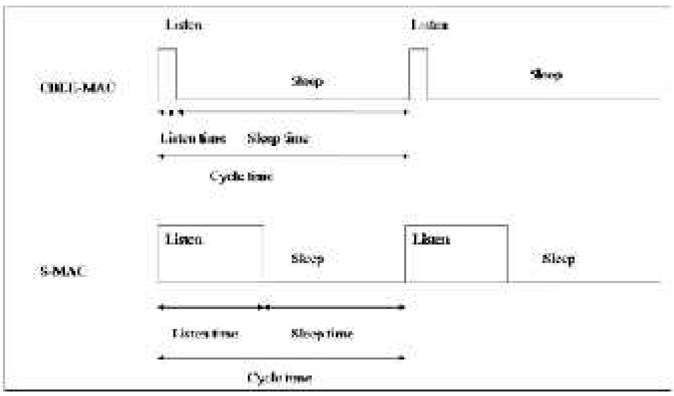


Fig 8. Listen time, sleep time and Cycle time in S-MaC & CBEE-MAC

XVII. CBEE-MAC Algorithm

Let Ni[ ], Nj[ ], , Nz[ ] be the array that stores number of neighbors of all nodes and let Ei[ ] ....,Ez[ ],be the array that stores the energy values of the particular node ij, ...z. Algorithm 1 is Communication algorithm, algorithm 2 is cluster formation algorithm, algorithm 3 is synchronization algorithm, algorithm 4 is cluster head election algorithm and algorithm 5 is cluster head maintenance algorithm.

For intra cluster CBEE-MAC:

1. Source node will send SYNC message to Cluster head (CH) which will then search the corresponding destination node. Sender will then send RTS to the receiver via CH and the receiver will reply with CTS to the sender via CH. Upon receiving of the CTS, the actual transmission of data packets takes place directly between sender and the receiver.
2. **For Inter cluster CBEE-MAC:**

Sender will send SYNC message to cluster head of its own cluster which will then search the corresponding receiver in its own cluster and if not found will pass the SYNC message to the other cluster through gateway and if the receiver is found then the sender will send the RTS packet to receiver via CH1-Gateway-CH2 and the receiver will reply with a CTS packet to the sender via CH2-Gateway-CH1. Upon receiving of the CTS actual transmission of data occurs between sender and receiver via the gateway.

Algorithm 3: Cluster Formation Algorithm

Let us consider a node say Ni. Now we will take in to account all other nodes which are at one hop distance from node Ni. All the nodes which are at one hop distance from Ni and including Ni will form one virtual cluster. Anyone more nodes which are common for two or more cluster are called as border node. And the border node has active participation during inter-cluster communication is called as gateway. Gateway at any time can only handle one work assigned to it i.e. if it is under supervision of one master node at a time it cannot participate under the supervision of another master. In other words gateway will be active for communication of one cluster at a time.

Algorithm 3: Synchronization Algorithm

The synchronization is achieved by exchange of SYNC packets with cluster head (CH) after everyone synchronization period. And all other nodes will synchronize with the cluster head in the cluster as the cluster head (CH) acts as the master and all other cluster nodes are its slaves.

Algorithm 5: Cluster Head Maintenance Algorithm

Let Eavg=average energy of all the nodes in a cluster.
Let ECH=energy of the Cluster Head
If (ECH > (80% of Eavg)) then set CH to node i;
Else if (ECH < (80% of Eavg)then
CH election ();
End if

XVIII. Experiments

The node configuration parameters specify the components that we want to simulate in each node and will be used in later node configuration step. Running parameters include simulation time, trace file name, nam file name. It has node configuration parameters and code configuring S-MAC parameters as mentioned in appendix and as discussed in Figure 35. In addition to this it has some lines of codes which are common for all wireless simulation.

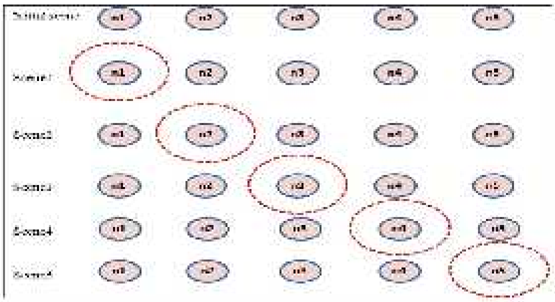


Fig 9. : Five static nodes representing various stages of S-MAC simulation

Name	Comment
syncFlag_	If it is set to 1, S-MAC runs with periodic sleep. If it is set to 0, S-MAC runs without periodic sleep.
dutyCycle_	The value of duty cycle in percent. It controls the length of sleep. If not set, ns-2 uses the default value 10%. This parameter is active only when syncFlag_ is set to 1.
selfConfigFlag_	If it is set to 1, all S-MAC nodes follow the schedule initialization algorithm. If it is set to 0, the schedule start time (first listen period start time) for each node is user-configurable.

Fig 10. S-MAC Interactive Parameters

The following statement sets the random seed value for random number generator. If we want NS-2 to produce different results every time we run the simulation (independent replications), the seed value should be zero. If we expect reproducible simulation results, the seed value can be any non-zero integer number.

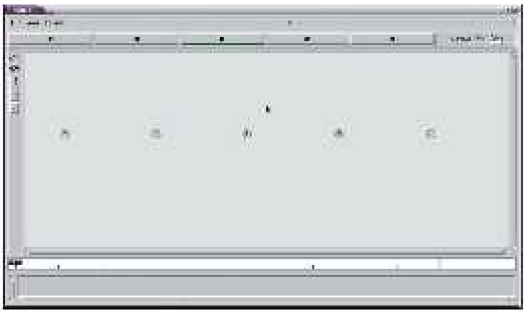
The next step is node configuration. In NS-2, node is the basic simulation entity and can be configured to have different components and characteristics in different simulations. In wired simulations, we normally create node objects directly using the default node configuration. But in wireless simulations, we must explicitly specify all components that each node object will have, before actually creating node objects. The node configuration parameters have been chosen at the beginning and stored in tel variables (in the form of $opt >>. In this step, we actually configure nodes with those variables. The node configuration command is shown as below. These options are easy to understand according to their names. The last three options turn on or off the trace options at AgentiRouterlMAC levels. In this example, we decide to turn tracing on
at the agent and router level only.

```
#configure node setting
$ns_ node-config -adhocRouting Soptfrp) \
-llType $opt (1l) \
-mac'lype $opt (mac) \
-ifqType $opt (ifq) \
-ifqLen $opt (ifqlen) \
-antType$opt (ant)   \
-propType $opt (prop) \
-phy'Type $opt (netif) \
-channelType $opt ( chan) \
-topoInstance $topo \
-agent Trace ON \
-routerTraceON \
-macTrnce ON \
-movemenr'lrace OFF \
-energyModel $opt (energymodel) \
-idlePower 1.0 \
-rxPower 1.4 \
-txPower 1.7 \
-sleep Power 0.002 \
-transitionPower 0.055 \
-transitionTime 0.0 15 \
-initialEnergy $opt (initialenergy)
Sns   setWtrelessNewTmce    ON
```

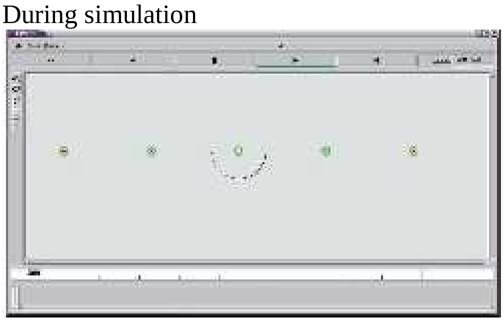
The next step is to define the traffic model. We should set up an agent at the transportation layer. Since we are studying the behaviors of S-MAC, UDP agent is a better choice than TCP agent, because UDP is quite simple and connectionless. The following code creates a UDP agent and attaches it to the source node. Accordingly, a Null agent is created and attached to the sink node. Then we connect the UDP agent and null agent together, which establishes a virtual path between the source node and the sink node. We also attached CBR traffic to UDP agent.

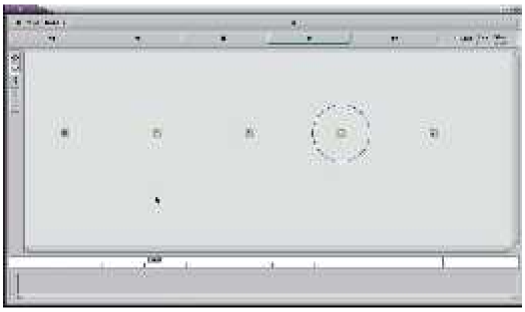
XIX. Results

Before simulation



During simulation





XX. CONCLUSION

We have extensively evaluated the S-MAC protocol and proposed a new protocol named "Cluster Based Energy Efficient Medium Access Control (CBEE-MAC)" protocol, which achieves energy savings over S-MAC. The factors affecting the energy utilization are identified and a new clustering mechanism is introduced through CBEE-MAC. This mechanism significantly reduces synchronization overhead and redefines the communication procedure between nodes. The key factors that account for energy savings are:

• Reduced listen time in cluster nodes
• Cluster head handling the data forwarding and
• Low control packet overhead

Our new protocol CBEE-MAC can achieve more energy savings than existing S-MAC. Above all designing a MAC protocol which can improve energy-efficiency to extend network lifetime in wireless sensor networks is a challenging problem. It is mainly due to stringent resource constraint both in sensor nodes and in wireless media. Several energy-efficient medium access control protocols that have been proposed by the researchers are presented in this paper. The design of an optimized MAC protocol for energy efficiency also depended on the actual application. However, no specific MAC protocol has been accepted as a standard. Another reason is the lack of standardization at lower layers (physical layer) and the sensor hardware.

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