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Performance Evaluation of Energy Efficient MAC Protocols for Wireless Sensor Network

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Abstract: **Wireless Sensor Network (WSN) is a collection of sensing devices that communicates with the wireless node. Packet Collision, Idle Listening, Overhearing and Protocol Overhead are problems in Wireless Sensor Network that leads to energy wastage. In Wireless Sensor Networks (WSNs), the main drawback is energy consumption. Idle listening is one of the most significant sources of energy consumption. In order to limit this problem many synchronous and asynchronous approaches have been proposed. Synchronous approaches reduce the idle listening by sharing schedule information. Exchange of schedule information again results in extra overhead on energy consumption. Asynchronous approach (RI-MAC) uses receiver initiated beacon to do same. In this thesis, S-MAC and RI-MAC protocol are analyzed and evaluated. The major performance parameters are Idle Listening and Energy Wastage.**

Keywords: **Wireless Sensor Network (WSN), Protocol Overhead, S-MAC and RI-MAC protocol.**

I. INTRODUCTION

Wireless networking is comprised of number of numerous sensors and they are interlinked or connected with each other for performing the same function collectively or cooperatively for the sake of checking and balancing the environmental factors. This type of networking is called as Wireless Sensor Networking.

Wireless Sensor Network is a group of sensor nodes work collaboratively to perform the task. It consists a number of distributed autonomous sensors to monitor the physical or environmental conditions then pass the data through the network to the base station. A sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission.

Sensor Node Architecture:

A sensor node typically consists of five main parts: one or more sensors gather data from the environment. The central unit in the form of a microprocessor manages the tasks. A transceiver communicates with the environment and a memory is used to store temporary data or data generated during processing. The battery supplies all parts with energy. To assure a sufficiently long network lifetime, energy efficiency in all parts of the network is crucial.

The development of sensor nodes is included in: Increasing device complexity on microchips, High performance, wireless networking technologies, A combination of digital signal processing and sensor data acquisition, Advances in the development of Micro-Electro Mechanical Systems (MEMS).

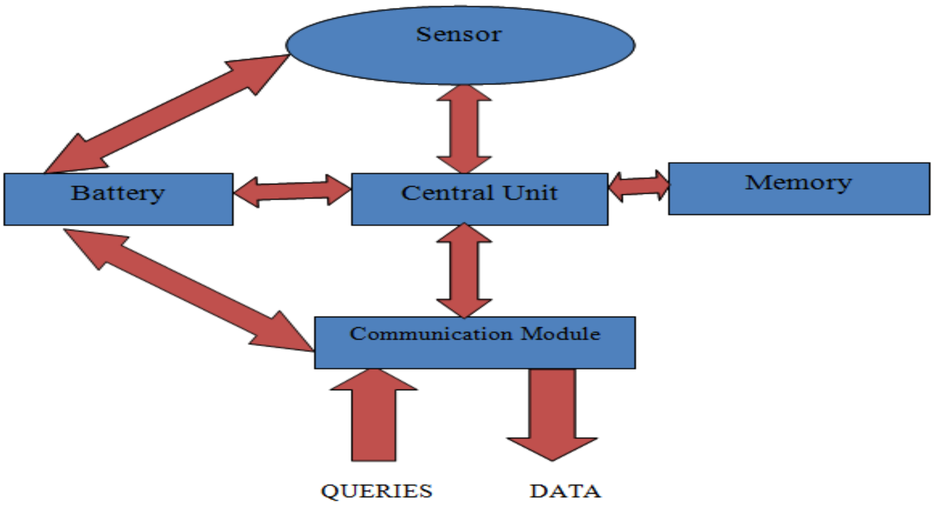

Fig 1.1 Sensor Node Architecture

Features of Sensor Node:

- Accuracy
- Environmental condition - usually has limits for temperature/ humidity
- Range - Measurement limit of sensor
- Calibration - Essential for most of the measuring devices as the readings changes with time
- Resolution - Smallest increment detected by the sensor
- Cost
- Repeatability - The reading that varies is repeatedly measured under the Same environment.

Characteristics of WSN:

The main characteristics of a WSN include:

- Deeply distributed architecture
- Autonomous operation
- Energy conservation
- Scalability
- Data centric network

II. RELATED WORK

This paper proposes S-MAC, a Medium Access Control (MAC) protocol designed for wireless sensor networks. Wireless sensor networks use battery-operated computing and sensing devices. A network of these devices will collaborate for a common application such as environmental monitoring. These characteristics of sensor networks and applications motivate a MAC that is different from traditional wireless MACs. Energy conservation and self-configuration are primary goals, While per-node fairness and latency are less important. S-MAC uses a few novel techniques to reduce energy consumption and support self-configuration. It enables low-duty-cycle operation in a multi hop network. Nodes form *virtual clusters* based on common sleep schedules to reduce control overhead and enable traffic-adaptive wake-up. S-MAC uses in-channel signaling to avoid overhearing unnecessary traffic.

A new power conservation scheme for multi-hop ad hoc networks. A virtual backbone consisting of special nodes (coordinators) is used for the power saving algorithm and routing. This paper presents a new distributed algorithm for constructing a connected dominating set (CDS) that is used to construct and maintain the virtual backbone of the network.

This scheme includes a message history based variable sleeping time for the non-coordinators. Simulations indicate that scheme results in better power conservation than other practical schemes discussed in the literature if the network has a sparse message density. First, it presents a new algorithm for maintaining and constructing the backbone. Secondly, it propose a power saving protocol, which allows the nodes to sleep for varying amounts of time depending on the message history of that node.

The problem of *idle listening* is one of the most significant sources of energy consumption in wireless sensor nodes, and many techniques have been proposed based on *duty cycling* to reduce this cost. This paper present a new *asynchronous* duty cycle MAC protocol, called *Receiver-Initiated MAC* (*RI-MAC*), that uses receiver-initiated data transmission in order to efficiently and effectively operate over a wide range of traffic loads. The performance of RI-MAC through detailed NS-*2* simulation and through measurements of an implementation in TinyOS in a testbed of MICAz motes.

Wireless Sensor Networks are appealing to researchers due to their wide range of application potential in areas such as target detection and tracking, environmental monitoring, industrial process monitoring, and tactical systems. Various MAC protocols with different objectives were proposed for Wireless Sensor Networks. In this paper, first outline for the sensor network properties that are crucial for the design of MAC layer protocols. Then, it describes several MAC protocols proposed for sensor networks emphasizing their strengths and weaknesses.

III. PREVIOUS IMPLEMENTATIONS

3.1 S-MAC:

S-MAC stands for Sensor MAC. This protocol is used to reduce the energy consumption in collision, idle listening, overhearing. In this protocol every node has two states namely Sleep state and Listen state. In this nodes can receive and send the data in a listen period itself.

The Sensor MAC protocol is a fixed duty cycle approach. It is simple and effective to reduce the idle listening problem. The S-MAC protocol is widely used in WSNs for energy conversation. There are three major sources of energy consumption are identified. These are:

- ***Collision***: Energy wastage due to retransmitting the collided packet.
- ***Overhearing***: It occur when it listen to node transmission that are not intended of it.
- ***Idle Listening***: It occur when a node listen to receive a packet at the time of no transmission.

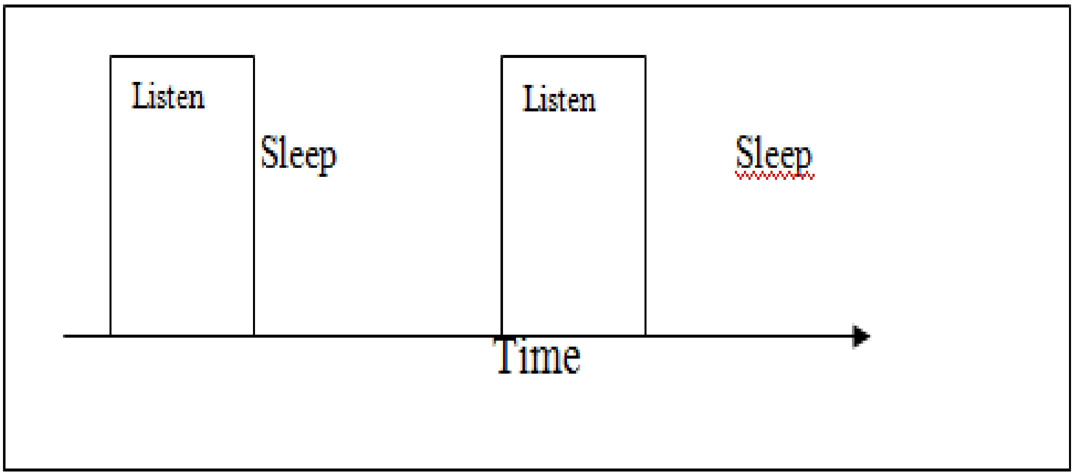

Fig 1.2 Overview of S-MAC

Characteristics of S-MAC:

The characteristics of S-MAC are: It forms nodes into a flat, pee to peer topology. Like clustering protocol, S-MAC doesn't require cluster head. In this, nodes are form by virtual cluster by using common schedules, it communicate directly with peers.

3.2 Maintaining Synchronization:

The before sending packets in S-MAC maintain a synchronization that are: Before each node starts a periodic listen and sleep period, it chooses a schedule table and exchange with neighbors. Each node maintains a schedule table. Initial schedule is established by synchronizer, Follower. They follow some rules to join the table. To maintain the schedule table it uses the clock drift. It can update the table by using SYNC packet.

Collision Avoidance:

If the multiple neighbors are wanted to take to a node, at the same time they try to send which node as start to listening. In this case they use medium for contention. In S-MAC follow some procedures, such as virtual and physical carrier sense and RTS/CTS exchange the hidden problem. If a node receives a packet destined to another node, it knows how long to keep silent from this field. The node records this value in a variable called the network allocation vector (NAV) and sets a timer for it. If the NAV value is not zero, then the node determines the medium is busy. This is called virtual carrier sense.

3.3 Overhearing Avoidance:

In S-MAC the Overhearing Avoidance includes:

S-MAC tries to avoid overhearing by letting interfering nodes go to sleep after they hear an RTS or CTS packet. This approach prevent neighboring nodes, because DATA packets are normally longer than the control packets. At which nodes should sleep when there is an active transmission in progress. Duration field in each transmitted packet indicates how long the remaining transmission will be. So if a node receives a packet destined to another node, it knows how long it has to keep silent.

3.4 Message Passing:

The Message Passing includes: A *message* is the collection of meaningful, interrelated units of data. The receiver usually needs to obtain all the data units before it can perform in-network data processing or aggregation. Transmitting a long message as a packet is disadvantageous as the re-transmission cost is high. Fragmentation into small packets will lead to high control overhead as each packet should contend using RTS/CTS. Fragment message in to small packets and transmit them as a burst.

3.5 RI-MAC Design:

The operation of RI-MAC, in which the data frame transmission, is initiated by the receiver node. In this, each node periodically wake up by using its own schedule before that it check if there is any incoming DATA frames is available, if it means turning on its radio, a node immediately broadcast a beacon frame. If the medium is idle, it announcing that it is awake and ready to receive a beacon frame. RI-MAC significantly reduces the amount of time a pair of nodes occupy the medium before they reach a rendezvous time for data exchange.

3.6 Beacon Frames

It always contains the SRC field, which is the address of source transmitting node of the beacon. A beacon with *only* a Src field a *base* beacon. A beacon can also include two optional fields, depending on the roles the beacon serves: *Dst*, for destination address, and *BW*, for back off window size. The duty cycle in RI-MAC is controlled by a parameter called the *sleep interval*, which determines how often a node wakes up and generates a beacon to poll for pending DATA frames.

3.7 Dwelled Time for Queued Packets:

After receiving a data frame, it waits for some time to send a queue packet to it immediately. This extra time is referring to DWELL TIME. The dwell time in RI-MAC is set by the contending senders. The duration of the dwell time is defined as the BW value from the last beacon plus SIFS and the maximum propagation delay. Based on the channel allocation the BW value is automatically adjusted.

3.8 Collision Detection and Retransmission:

RI-MAC greatly reduces the cost for detecting collisions and recovering lost DATA frames. As a sender can transmit DATA frame only upon receiving a beacon, and since the back off window size is explicitly controlled by the intended receiver, the receiver knows the maximum delay before a DATA frame's arrival. This delay can be calculated from the BW value in the previous beacon.

3.9 Beacon-On-Request:

In this request, a sender can wake up for data frames transmission, to broadcast a beacon by using CCA checks. In this beacon, the sender *sets* the Dst field to the receiver's address, If the receiver *happens* to be active, it generates a beacon in response after some random delay longer than the BW announced in the received beacon from *S*. This beacon generated by the receiver on request of the sender allows the sender to transmit the pending DATA frame immediately, rather than waiting until the next scheduled beacon transmission.

IV. SYSTEM IMPLEMETNATION

MAC stands for Medium Access Control. A MAC layer protocol is the protocol used to control the access of physical transmission medium on LAN. It tries to ensure that two nodes are not interfering with each other at the time of transmissions. It ensures that the channel can be accessed by multiple users. The task of MAC sub layer is to provide fair access to channels by avoiding possible collisions.

Objective:

The Medium Access Control protocols for the Wireless Sensor Networks have to achieve two objectives:

- The first objective is the creating a infrastructure for the sensor network and the MAC scheme used to establish the communication link between the sensor nodes.
- The second objective is to share the communication medium fairly and efficiently.

4.1 RI MAC:

An asynchronous duty cycle MAC protocol is called RI-MAC protocol. It stands for Receiver Initiated MAC protocol. It uses a reliable data transmission in a beacon packet. In order to operate a wide range of traffic loads efficiently and efficiently by using receiver initiated transmission. RI MAC attempts to minimize the time a sender and its intended receiver occupy the wireless medium to find a rendezvous time for exchanging data, while still decoupling the sender and receiver's duty cycle schedules.

4.2 RELATED WORK:

The contribution of RI-MAC work as follows:

- It not only reduces overhearing, it also achieve lower collision problem and it reduce the cost also.
- It significantly improves the packet throughput and delivery ratio especially at the time of burst traffic or transmission of hidden nodes.
- The receiver increases the channel utilization as well as the traffic load increases.

The RI-MAC follows some mechanism such as:

- PTIP
- LPP

4.3 OVERVIEW:

RI-MAC significantly reduces the amount of time a pair of nodes occupy the medium before they reach a rendezvous time for data exchange. It transmits a data frames among senders to the same receiver. It is mainly controlled by receiver. It also decouples the sender and receiver duty cycle schedules.

RI-MAC also reduces overhearing, as a receiver expects incoming data only within a small window after beacon transmission. Together with the lower cost for detecting collisions and recovering lost DATA frames, RI-MAC achieves higher power efficiency, especially when the network load increases.

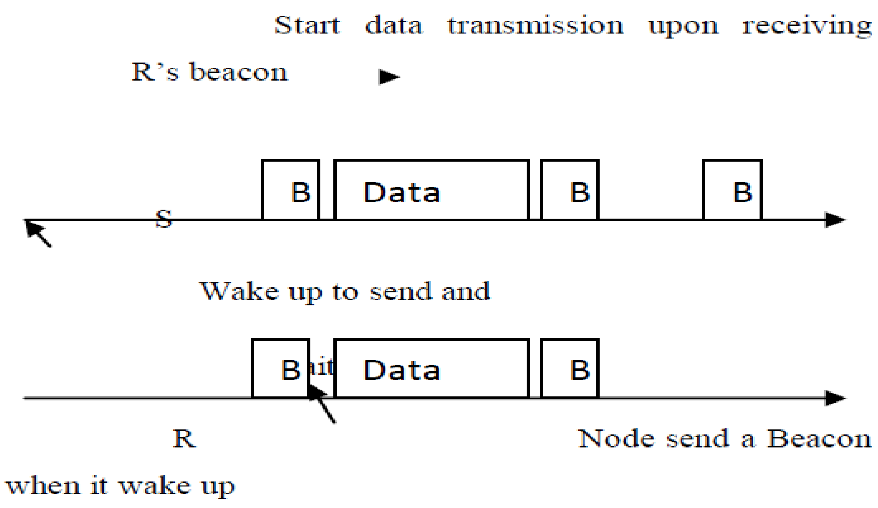

Fig 1.3 Overview of RI-MAC

4.4 BEACON FRAMES:

It always contains the SRC field, which is the address of source transmitting node of the beacon. A beacon with *only* a Src field a *base* beacon. A beacon can also include two optional fields, depending on the roles the beacon serves: *Dst*, for destination address, and *BW*, for back off window size.A node that receives a beacon can determine which fields are present in the beacon by looking at the size of the beacon; A beacon in RI-MAC plays two roles: acknowledgment to previously received DATA, request for the initiation of the next DATA transmission.

4.5 Dwelled Time For Queued Packets:

After receiving a data frame, it waits for some time to send a queue packet to it immediately. This extra time is referring to DWELL TIME. The dwell time in RI-MAC is set by the contending senders. The duration of the dwell time is defined as the BW value from the last beacon plus SIFS and the maximum propagation delay. Based on the channel allocation the BW value is automatically adjusted. This self-adaptation helps RI-MAC using the shortest waiting time possible under light channel contention while avoiding collisions under heavy channel contention.

4.6 Data Frame Transmission From Contending Senders:

The contending senders have two objectives for handling the transmission

- Minimize the active time of a receiver for power efficiency;
- Minimize the cost for collision detection and recovery of lost data, whether or not senders are hidden to each other.

4.7 Collision Detection And Retransmission:

RI-MAC greatly reduces the cost for detecting collisions and recovering lost DATA frames. As a sender can transmit DATA frame only upon receiving a beacon, and since the back off window size is explicitly controlled by the intended receiver, the receiver knows the maximum delay before a DATA frame's arrival. This delay can be calculated from the BW value in the previous beacon.

V. EVALUATION RESULT

Average Energy for RI-MAC and S-MAC protocol:

In Wireless Sensor Networks (WSNs) in which each sensor node randomly and alternatively stays in an active mode or a sleep mode. The active mode consists of two phases, called the full-active phase and the semi-active phase. By using cluster node, 48 nodes are created.The evaluation is carried out with the ns2 simulations by performing several experiments that illustrate the performance of We compare the performance of S-MAC and RI-MAC according to the performance metrics. We calculate the energy and delay of the both protocols and shows that the performance of RI-MAC is better than S-MAC.

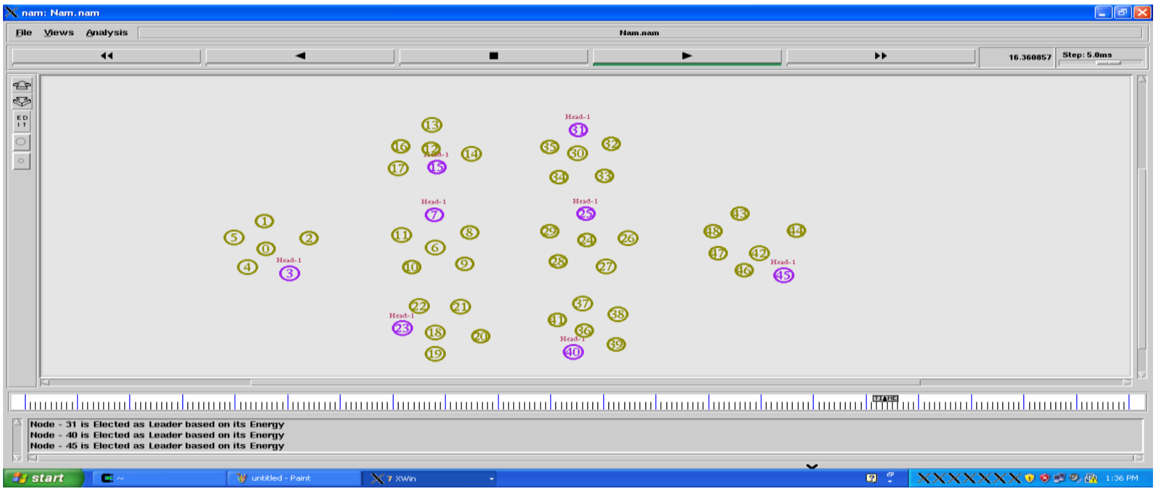

Fig 1.4: Node Creation

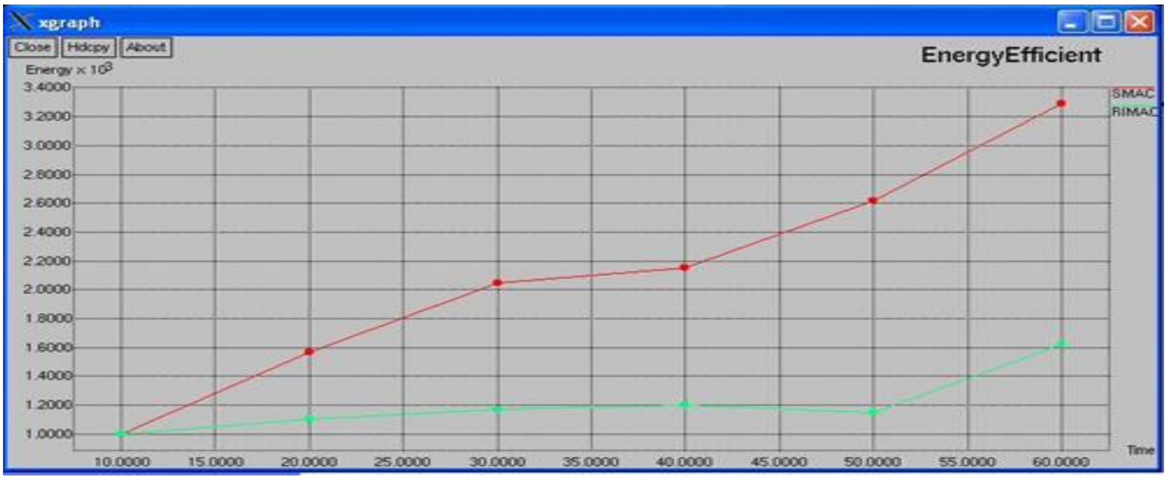

Fig 1.5 Energy Efficient

A Wireless Sensor Network (WSN) is a collection of nodes organized into a cooperative network. Each node consists of processing capability which acts as transceiver. Most of the protocols use clusters in order to provide energy efficiency and to extend the network lifetime. Each cluster first elects a node as the Cluster Head (CH), and then, the nodes in every cluster send their data to their own Cluster Head. The Cluster Head sends its data to the base station. This data transfer can be performed in two alternative ways. Either directly, in the case in which the Cluster Head is located close to the base station, or via intermediate cluster heads.

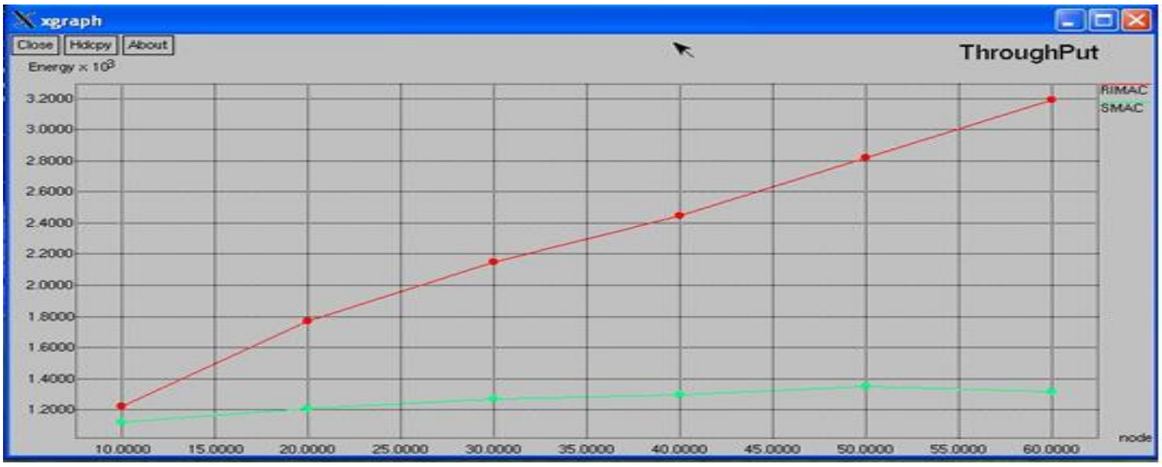

Fig 1.6 Throughputs

Throughput is typically defined as the rate at which messages are serviced by a communication system. It is usually measured either in messages per second or bits per second. In wireless environments it represents the fraction of the channel capacity used for data transmission.

Many protocols in Wireless Sensor Networks use packet delivery ratio (PDR) as a metric to select the best route, transmission rate or power. PDR is normally estimated either by counting the number of received hello/data messages in a small period of time, i.e., less than 1 second, or by taking the history of PDR into account. The first method is accurate but requires many packets to be sent, which costs too much energy. The second one is energy efficient, but fails to achieve good accuracy.A Sensor Network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable. Every sensor node is equipped with a transducer, microcomputer, transceiver and power source

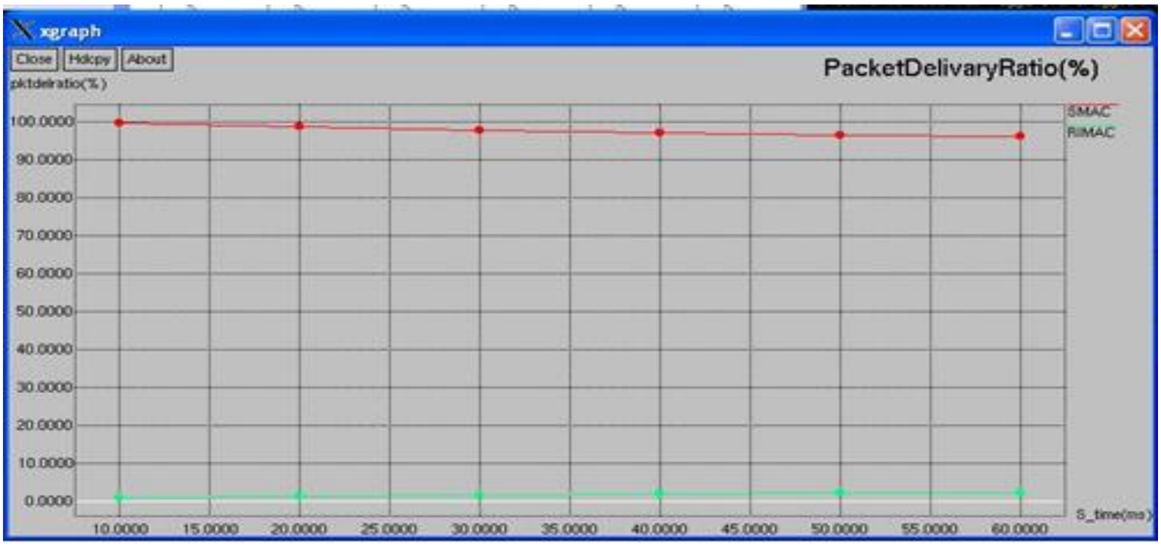

Fig 1.7: Packet Delivery Ratio

VI. CONCLUSION

S-MAC, RI-MAC protocols are used to solve the idle listening problem. Based on the thesis, low energy efficiency is needed to transmit the packets from source to destination at the time of solving the ldle listening problem. In future energy models can be used to find out the energy efficiency of MAC protocols. One of the key applications of the sensor networks which is widely adapted due to its huge number of implementations and usages, in the MAC protocols. Although, this application is known for its high demands of energy in order to perform its tasks in the best manner as many as possible. Since the main drawback that faces most in the transmission of packets in sensor networks is the fact that the sensor network suffers from a very limited power supply. Therefore, the need to optimize the energy consumption in idle listening problem is a fact must be faced. Since most the energy savings research was focusing on minimizing the energy consumed by the radio component (RF radio) in the sensor nodes by reducing the number of messages transmitted and received, Considering the energy consumed and the sensing components in the sensor nodes which also attributed to a respectful amount of energy consumption. Therefore the idle listening problem to be solved by using MAC protocols. In this scheme, it uses types of MAC protocols to solve the idle listening problem. S-MAC uses sleep and active period by fixing time synchronization. RI-MAC protocols uses, a short beacon frame from receiver to sender to send the packets from sender to receiver. Finally it proven that RI-MAC is the best way than that of S-MAC protocol.

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