Novel approach for Improvisation of Medium Access Protocol for Wireless Sensors Networks

[1]**B Naga Naveen,** [2]**K Manikandan**

[1,2]School of Computing Science and Engineering, VIT University, Vellore, India.

Abstract

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. We expect sensor networks to be deployed in an ad hoc fashion, with individual nodes remaining largely inactive for long periods of time, but then becoming suddenly active when something is detected. These characteristics of sensor networks and applications motivate a MAC that is different from traditional wireless MACs such as IEEE 802.11 in almost every way: energy conservation and self-configuration are primary goals, while per-node fairness and latency are less important

Keywords

Energy Efficiency, Medium Access Control, Wireless Sensors Networks, TDMA

I. Introduction

Wireless sensor networking is an emerging technology. That has a wide range of potential applications including environment monitoring, smart spaces, medical systems and Robotic exploration [1]. 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. Typically, these nodes coordinate to perform a common task. Designing wireless sensor networks with the capability of prolonging network lifetime catch the attention of many researchers in wireless network field. Contrasts with Mobile Ad Hoc Network system (MANET), Wireless Sensor Networks (WSN) designs focused more on survivability of each node in the network instead of maximizing data throughput or minimizing end-to-end delay[8]. In this paper, we will study part of data link layer in Open Systems Interconnection (OSI) model, called medium access control (MAC) layer, which sits on top of physical layer as shown in Fig. 1 below. Since the MAC Development of Energy Aware TDMA-based MAC Protocol for Wireless Sensor Network System layer controls the physical (radio), it has a large impact on the overall energy consumption, and hence, the lifetime of a node.

II. MAC layer

The Mac (Medium Access Protocol) Protocol comes under data link layer in OSI basic reference model.
Many reasons related to MAC paradigms lead to energy waste and WSN life reduction, such as
A. Idle listening: a node doesn't know when will be receiving a frame so it must maintain permanently its radio in the ready to receive mode [2].
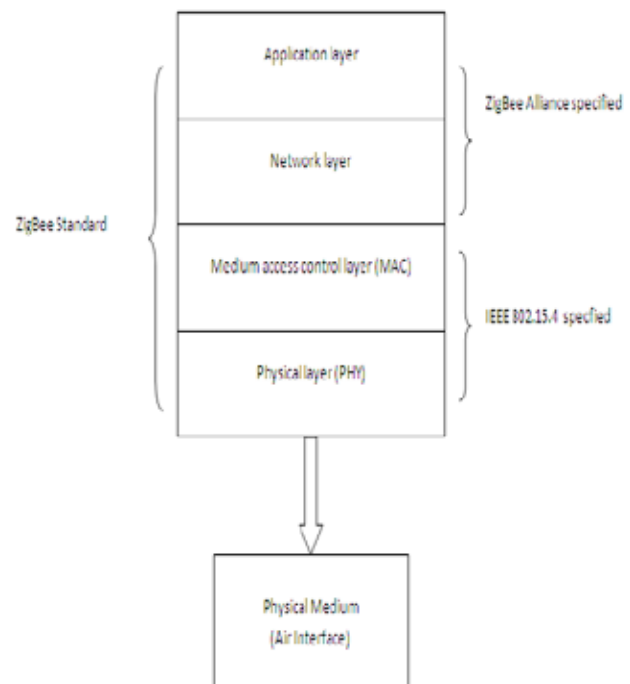

Fig. 1: MAC Layer

B. Collisions: A collision can occur when a node receives two signals or more simultaneously from different sources that transmit at the same time [3].
C. Overhearing: occurs when a node receives packets that are not destined to him or redundant broadcast.
D. Protocol Overhead: can have several origins as the energies lost at the time of transmission and reception of the control frames.
E. Overmitting: occurs when a sensor node sends data to a recipient who is not ready to receive them.
F. Packets size: The size of the messages has an effect on the energy consumption of the emitting and receiving nodes.
G. Traffic fluctuation: The fluctuations of the traffic load can lead to the waste a node's energy reserves. Therefore, the protocol should be traffic adaptive [4].In this paper we majorly concentrate on the IEEE 802.11, TDMA, and Energy Efficiency.

II IEEE 802.11

IEEE 802.11 is a set of standards for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802) [5]. The base current version of the standard is IEEE 802.11-2007. The 802.11 family consists of a series of over-the-air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols, which are amendments to the original standard. 802.11-1997 was the first wireless networking standard, but 802.11b was the first widely accepted one, followed by 802.11g and 802.11n. Security was originally purposefully weak due to export requirements of some governments, and was later enhanced via the 802.11i amendment after governmental and legislative changes. 802.11n is a new multi-streaming modulation technique..The segment of the radio frequency spectrum used by 802.11 varies between countries. In

the US, 802.11a and 802.11g devices may be operated without a license, as allowed in Part 15 of the FCC Rules and Regulations. Frequencies used by channels one through six of 802.11b and 802.11g fall within the 2.4 GHz amateur radio band. Licensed amateur radio operators may operate 802.11b/g devices under Part 97 of the FCC Rules and Regulations, allowing increased power output but not commercial content or encryption.

These are divided into the following types

A. 802.11-1997:

The original version of the standard IEEE 802.11 was released in 1997 and clarified in 1999, but is today obsolete. It specified two net bit rates of 1 or 2 megabits per second (Mbit/s), plus forward error correction code. It specified three alternative physical layer technologies: diffuse infrared operating at 1 Mbit/s; frequency-hopping spread spectrum operating at 1 Mbit/s or 2 Mbit/s; and direct-sequence spread spectrum operating at 1 Mbit/s or 2 Mbit/s. The latter two radio technologies used microwave transmission over the Industrial Scientific Medical frequency band at 2.4 GHz. Some earlier WLAN technologies used lower frequencies, such as the U.S. 900 MHz ISM band.
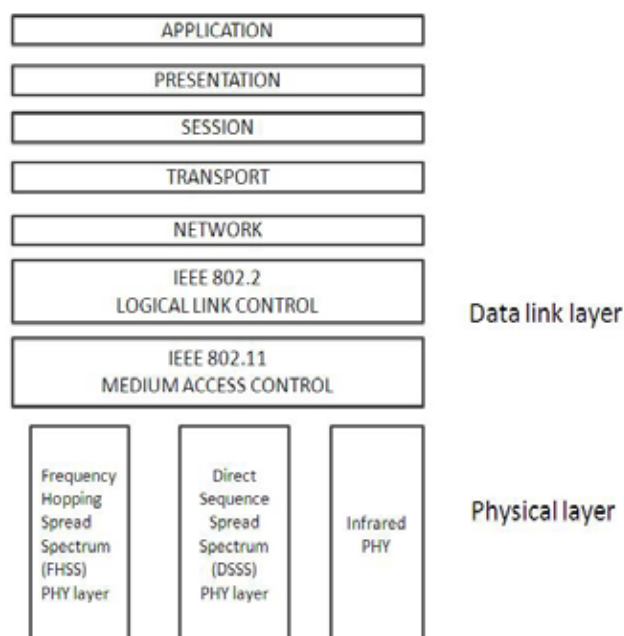

Fig. 2: IEEE Layer

B. 802.11a-1999:

The 802.11a standard uses the same data link layer protocol and frame format as the original standard, but an OFDM based air interface (physical layer). It operates in the 5 GHz band with a maximum net data rate of 54 Mbit/s, plus error correction code, which yields realistic net achievable throughput in the mid-20 Mbit/s.Since the 2.4 GHz band is heavily used to the point of being crowded, using the relatively unused 5 GHz band gives 802.11a a significant advantage. However, this high carrier frequency also brings a disadvantage: the effective overall range of 802.11a is less than that of 802.11b/g. In theory, 802.11a signals are absorbed more readily by walls and other solid objects in their path due to their smaller wavelength and, as a result, cannot penetrate as far as those of 802.11b. In practice, 802.11b typically has a higher range at low speeds (802.11b will reduce speed to 5 Mbit/s or even 1 Mbit/s at low signal strengths). However, at higher speeds, 802.11a often has the same or greater range due to less interference.

C. 802.11b-1999:

802.11b has a maximum raw data rate of 11 Mbit/s and uses the same media access method defined in the original standard. 802.11b products appeared on the market in early 2000, since 802.11b is a direct extension of the modulation technique defined in the original standard. The dramatic increase in throughput of 802.11b (compared to the original standard) along with simultaneous substantial price reductions led to the rapid acceptance of 802.11b as the definitive wireless LAN technology.802.11b devices suffer interference from other products operating in the 2.4 GHz band. Devices operating in the 2.4 GHz range include: microwave ovens, Bluetooth devices, baby monitors and cordless telephones.

D. 802.11g -2003:

In June 2003, a third modulation standard was ratified: 802.11g. This works in the 2.4 GHz band (like 802.11b), but uses the same OFDM based transmission scheme as 802.11a. It operates at a maximum physical layer bit rate of 54 Mbit/s exclusive of forward error correction codes, or about 22 Mbit/s average throughput.802.11g hardware is fully backwards compatible with 802.11b hardware and therefore is encumbered with legacy issues that reduce throughput when compared to 802.11a by ~21%.

E. 802.11g -2009:

802.11n is a recent amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output antennas (MIMO). 802.11n operates on both the 2.4GHz and the lesser used 5 GHz bands. The IEEE has approved the amendment and it was published in October 2009.Prior to the final ratification, enterprises were already migrating to 802.11n networks based on the Wi-Fi Alliance's certification of products conforming to a 2007 draft of the 802.11n proposal.

III. TDMA

TDMA is known as Time Division Multiple Access. It is a channel access method for shared medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using his own time slot. This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity. TDMA is used in the digital 2G cellular systems such as Global System for Mobile Communications (GSM), IS-136, Personal Digital Cellular (PDC) and iDEN, and in the Digital Enhanced Cordless Telecommunications (DECT) standard for portable phones. TDMA transmissions in multi hop networks usually determine the smallest length conflict free assignment of slots in which each link or node is activated at least once. This is based on the assumption that there are many independent point-to-point flows in the network .In sensor networks however often data are transferred from the sensor nodes to a few central data collectors.

Proposed MAC protocols for sensor networks provide either contention based access or time division multiple access (TDMA). The former, e.g., IEEE 802.11 [6], consume more energy than TDMA protocols because they waste energy in collisions and idle listening. Moreover, they do not give delay guarantees. TDMA protocols are more power efficient since nodes in the network can enter inactive states until their allocated time slots. They also eliminate collisions and bound the delay. For example, the TDMA protocol for a traffic monitoring network described in has a lifetime of 1,200 days compared with ten days using the IEEE 802.11 protocol. The main task in designing a TDMA schedule is to

allocate time slots depending on the topology and the node packet generation rates. A good schedule not only avoids collisions by silencing the interferers of every receiver node in each time slot but also minimizes the number of time slots hence the latency: The larger latency may require a higher data rate (and hence higher energy consumption) to satisfy a deadline [7]. We therefore try to find a TDMA schedule that minimizes the number of time slots. TDMA algorithms consider either one-hop or multi-hop scheduling. The former are for networks in which the nodes are one hop away from the base station and allocate time slots in the reverse channel depending on allocation request and deadline of the nodes. Because the base station is the common receiver of the transmissions, only one node can transmit in a slot. In some sensor networks however direct transmission from all sensor nodes to the base station may not be feasible nor power efficient.

Multi-hop TDMA scheduling is more challenging than one-hop scheduling because spatial reuse of a time slot may be possible: More than one node can transmit at the same time slot if their receivers are in non-conflicting parts of the network. There are two types of conflicts, namely, primary conflict and secondary conflict. A primary conflict occurs when a node transmits and receives at the same time slot or receives more than one transmission destined to it at the same time slot. A secondary conflict occurs when a node, an intended receiver of a particular transmission, is also within the transmission range of another transmission intended for other nodes. In the context of TDMA, the problem is to determine the smallest length conflict-free assignment of slots where each link or node is activated at least once [4].
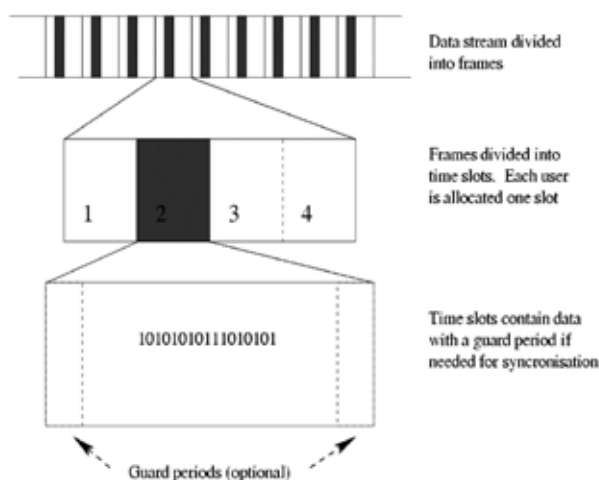

Fig. 3: Tdma Time slots

IV. EOMAC

Energy Efficient Optimal MAC Protocol for Wireless Sensor Networks (E0MAC) switches the radio between the sleep and listen modes and saves the energy. The hidden and exposed node problems are solved by using the RTS-CTS DATA-ACK sequence. A sensor node, which is not involved in the communication, once it receives RTS or CTS packet, enters the sleep mode. The Power Aware Multi-Access protocol (PAMAS)and Low Power Distributed MAC protocol (LPDM) use a separate signaling channel. The data channel radio is activated for a data transmission, by sending a control information in the signaling channel. In PAMAS, when a sensor node is involved in a transmission, the time duration of the transmission is informed to its neighbors, located within the radio range of the ongoing transmission, using the RTS-CTS message on the signaling channel. This saves the unnecessary wastage of energy by keeping the radio in the sleep mode instead of idle mode.

Pseudo code algorithm

Algorithms 1 send SYNC to neighboring nodes
Upon the SYNC packet initiating time, construct SYNC packet.
if (there is packet waiting to be sent) then
if (the packet is a unicast packet) then
data SoDt = the node ID of the destination.
else if (the packet is a broadcast packet) then
data SoDt = the node ID of the source.
endif
else
data SoDt = -1
end if

Algorithms 2 handle SYNC

Upon the reception of an SYNC packet time, update the schedule table
Get value of data SoDt field
if (data SoDt equals to my ID || data SoDt equals to the source's ID) then
dataSoRx_ = 1
endif
Update the schedule table

Algorithms 3 handleCounterTimer
Upon the timeout of the synchronization timer, regulate the sleep/wakeup cycles
if (data time of the cycle begins) then
if (dataSoRx_= 0) then
Activate the early-sleep mechanism
if (early-sleep mechanism is activated && no packet to send && it is my schedule) then
Go to sleep.
Initiate dataSoRx_to 0
else if (there's packet to send) then
Start carrier sense
endif
end if

Graded contention window should also be applied to early-sleep scheme. Otherwise, without this mechanism, something unwilling will happen, which will increase the end-to-end delay and waste energy. For example, SYNC packets with potential data packet, denoted as SYNC data, may lose channel competition. On the other hand, a certain SYCN packet which implies no data packet, denoted as SYNC no data wins. Their shared neighbors will hear this SYNC no data and hereby make a mistake decision that it should trigger early-sleep mechanism.

V. Simulations

In this paper the Simulation work is done by using NS2 (Network Simulator). NS2 is a discrete event network simulator. NS is used in the simulation of routing protocols, among others, and is heavily used in ad-hoc networking research. ns supports popular network protocols, offering simulation results for wired and wireless networks alike. It is popular in research given its open source model and online documentation. However, modeling is a very complex and time-consuming task in ns-2, since it has no GUI and one needs to learn scripting language, queuing theory

and modeling techniques. Of late, there have been complaints that results are not consistent (probably because of continuous changes in the code base) and that certain protocols are replete with bugs.

IEEE 802.11

Here in the below scenario the node 24 acts as a base station and the destination nodes is 4.And the data packet is transfer from the base station to the destination node.
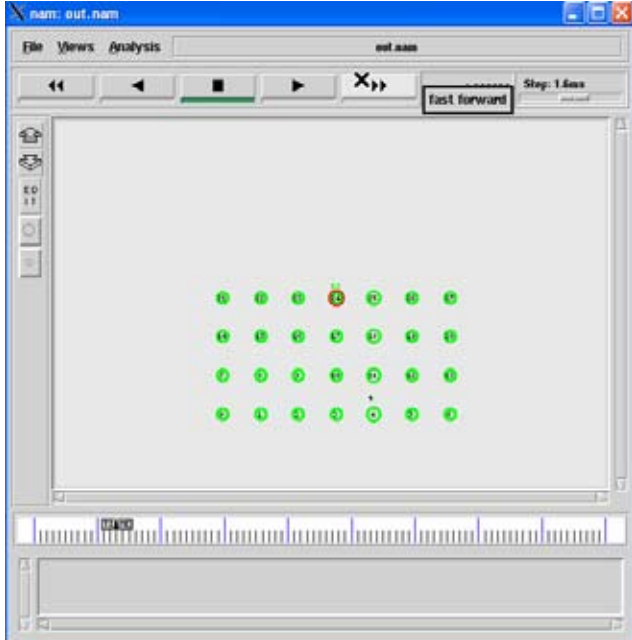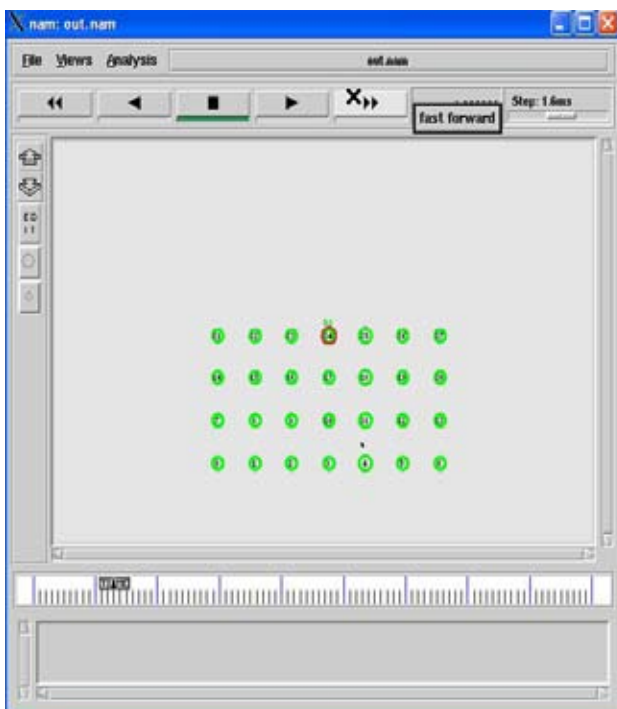
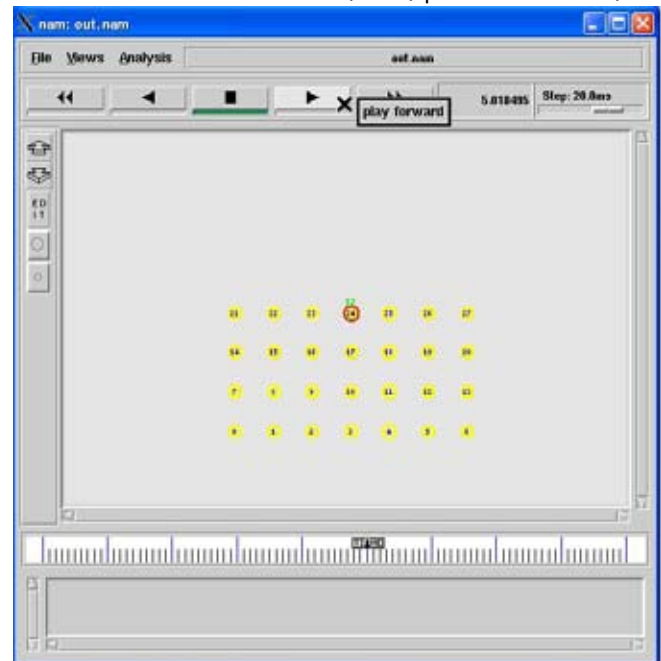

Fig. 4: IEEE 802.11

TDMA

Fig. 5: TDMA

Fig. 6: TDMA (after the packet dispatched)

Here in the above Fig. the yellow color of the nodes resembles that packet is dispatched.
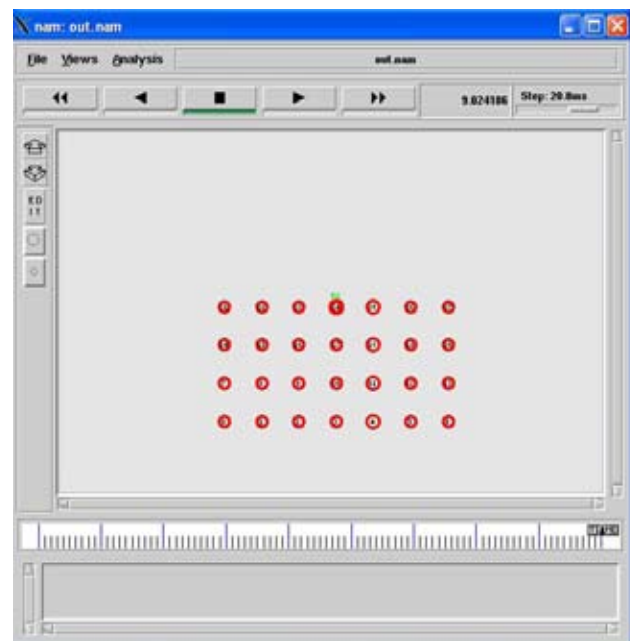

Fig. 7: TDMA (sleep state)

Here in the above Fig. the nodes turn red color for which the packet transfer is finished and its save the energy by going into sleep state.
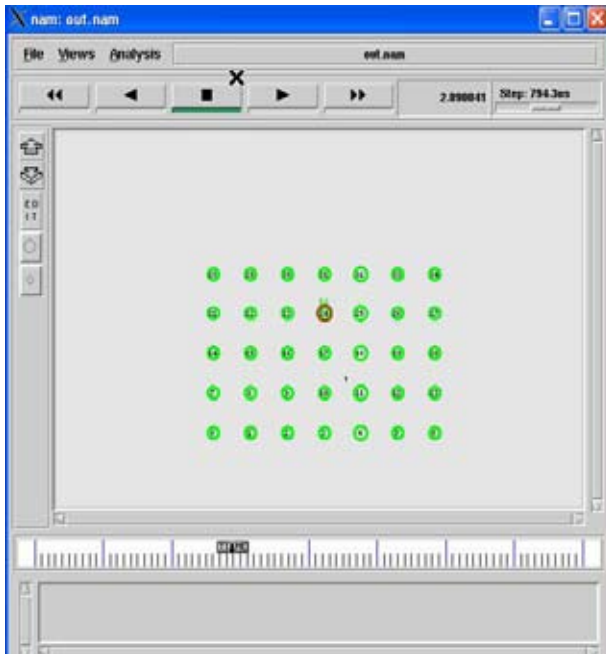
EOMAC

Case 1

Fig. 8: EOMAC (Energy Efficient Optimal MAC)

From case 1 we justify from the Fig. that node transfer the packet is done from the base station to the destination node in single hop.
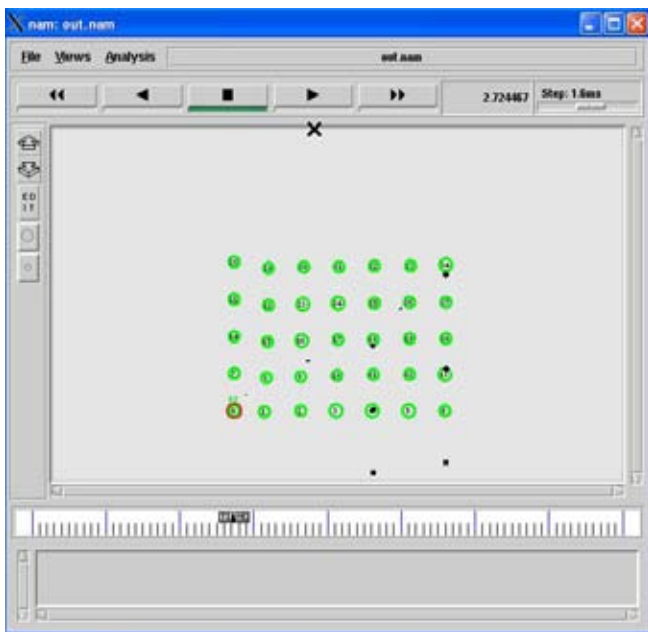
Case 2

Fig. 9: EOMAC (Energy Efficient Optimal MAC)
From case 2 we justify from the Fig. that node transfer the packet is done from the base station to the destination node in multi hop.

Source is (0), Intermediate node (18), Destination (24)

Due to this there are some packets droplets.

VI. Results
In this project we compared the energy efficiency and delay of Mac protocol with the help of Xgraphs to the new protocol EOMAC
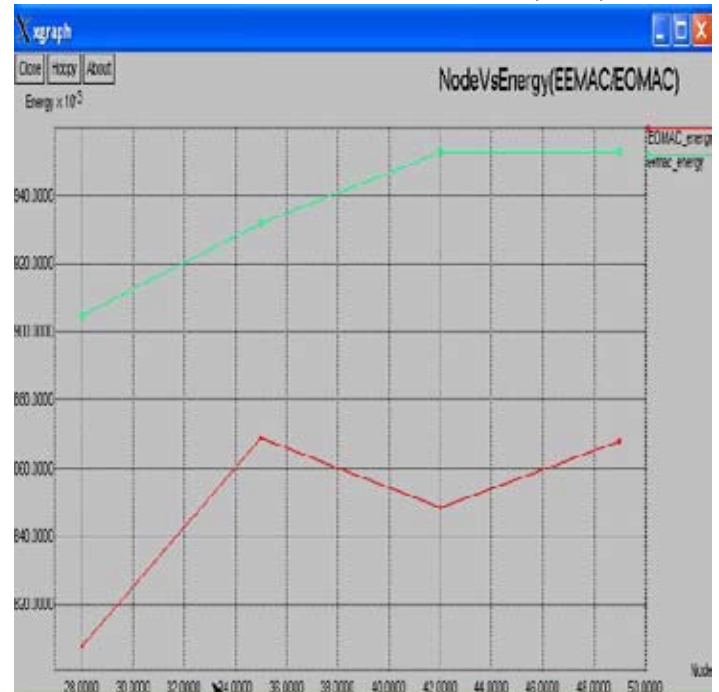
Node Vs Energy

Fig. 10: Comparison of EEMAC and EOMAC

In the above graph the comparison of energy efficient Mac and the energy optimal Mac in terms of energy.
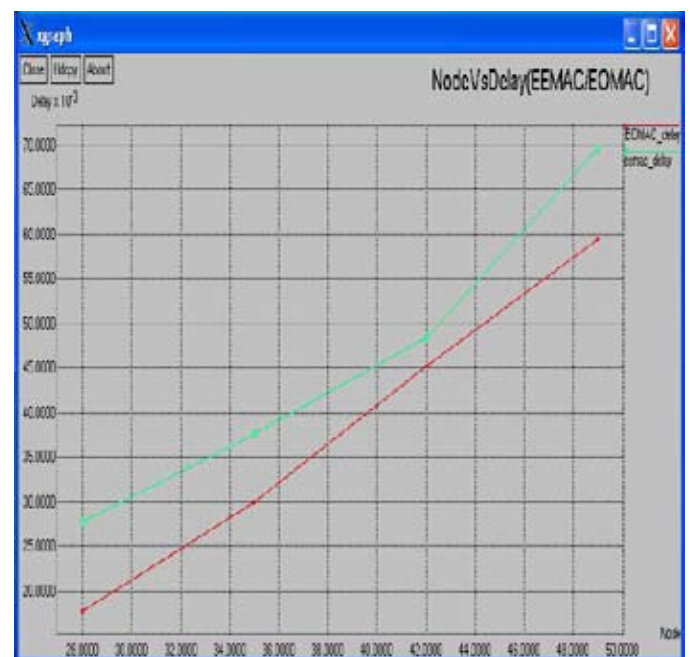
Node Vs Delay

Fig. 11: Comparison of EEMAC and EOMAC

In the above graph the comparison of energy efficient Mac and the energy optimal Mac in terms of delay.

References
[1] Zhenzhou Tang, Qian Hu "ALLEE-MAC:An Adaptive Low Latency and Energy Efficient Wireless Sensors Networks.2010 IEEE DOI 10.1109/AICT
[2] Cano, C. Bellalta, B.Sfairopoulou, A.Barcelo "A low power listening MAC with scheduled wake up after transmissions for WSNs vol-14 pp.221-223 ISSN-7798 April 2009.
[3] V. Bharghavan, A. Demers, S. Shenker, L. Zhang, "Macaw: A media access protocol for wireless lans," in Proceedings of the ACM SIGCOMM Conference, 1994.

[4] Haigang Gong, Ming Liu, Yinchi Mao, Li-jun Chen, Li Xie "Traffic Adptive MAC Protocol for Wireless Sensor Network" X.Lu and W.Zhaoc(Eds): ICCNMC 2005, LNCS 3619, pp.1134-1143,2005 Springer-Verlag Berlin Heidelberg 2005.

[5] Nadeem T Ashok Agrawala, "Performance of IEEE 802.11 based wireless sensors networks in noisy environments". IEEE 2005 ISSN:1097-2641.

[6] IEEE Standard 802.11. "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications" (1999).

[7] W. Ye, J. Heidemann, D. Estrin, "Medium Access Control with Coordinated Adaptive Sleeping for Wireless Sensor Networks," IEEE/ACM Trans. Net., vol. 12, no. 3, June 2004, pp. 493–506.

[8] Li De-liang Peng Fei, "Energy-efficient MAC protocols for Wireless Sensor Networks", information and communications technologies, Beihang University, Beijing, 100083, Mar 2009.

Manikandan K is working as a Asst. professor (Senior) in School of Computing Sciences and Engineering, VIT University, Vellore, India. He was the recipient of academic excellence award. He was the gold medalist of Anna University during his M.E. (CSE). His area of interest include MANET, Sensor networks, Cluster computing.

B Naga Naveen is currently pursuing M-Tech in Computer Science and Engineering in VIT University, Vellore India. Is area of interest including Wireless Sensors Networks and Artificial Intelligence.