ISSN 2229-5518

# ENERGY EFFICIENT MULTI LAYER PROTOCOL FOR WIRELESS SENSOR NETWORK

Mundlamuri kowshik
Electronics and Communication Engineering
Shiv Nadar University
Greater Noida, Uttar Pradesh, India
Km864@snu.edu.in

**Abstract –** In wireless sensor networks (WSNs), extensive life span requirement for diverse applications and limited energy storage ability of sensor nodes has led to the discovery of a new field for reducing the power consumed by nodes. To raise sensor node's life span, protocols have to be energy efficient so that they can reduce energy consumption in each layer mainly physical layer (i.e., power control), MAC layer (i.e., retransmission control) and network layer (i.e., routing protocol). In this paper, we explore various protocols in physical layer, Mac layer and Network layer to provide an energy efficient network.

**Key words-** Wireless Sensor Network (WSN), Energy Efficiency, C-MAC protocol, Leach protocol.



## Introduction

Wireless sensor network is a high and new technology consists of spatially scattered autonomous sensors to observe physical or environmental conditions such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a chief location. The more current networks are bi-directional, also enabling control of sensor activity. The advancement of wireless sensor networks was provoked by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring. [1]

The Wireless sensor network is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an inbuilt form of energy harvesting.

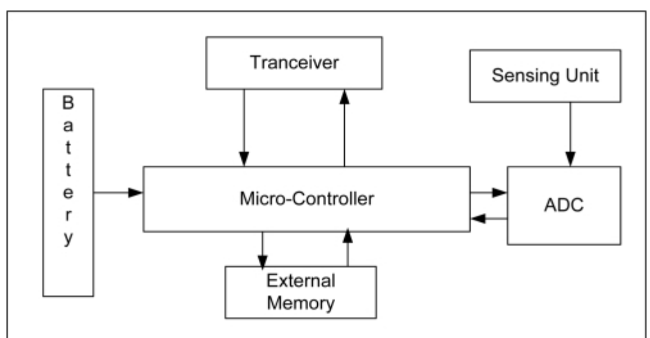


Fig 1: Architecture of sensor node [6]

The emerging field of wireless sensor networks combines sensing, computation, and communication into a single tiny device. Through highly developed mesh networking protocols, these devices form a sea of connectivity that extends the reach of cyberspace out into the physical world.[2]

Since the wireless sensor node is often placed in a hard-to-reach location, changing the battery regularly can be costly and inconvenient. An important aspect in the development of a wireless sensor node is ensuring that there is always adequate energy available to power the system.

Wireless sensor networks for long life span requisite of different applications and limited energy storage capability of sensor nodes has led us to find out new horizons for reducing power consumption upon nodes. To increase sensor node's life span, circuit and protocols have to be energy efficient so that they can make a priori reactions by estimating and predicting the energy consumption and come up with a new method of networking with low energy consumption without effective loss of other characteristics and variation in its topology to get maximum efficiency.

Researchers have devised many protocols for communication, and security in wireless networks life infrastructure based networks, ad-hoc networks, mobile networks etc. But as mentioned above, these protocols cannot be used directly due to resource constraints of sensor nodes for resources like limited battery power, communication capability, and computational speed. Much research has been done in recent years, investigating different aspects like, low power protocols, network establishments, routing protocol, coverage problems and the establishment of secure wireless sensor networks. But even after many efforts, there are still many design options open for improvement. Thus, there is a need to device a new protocol which enables more efficient use of scarce resources at individual sensor nodes for an application. [3]

Normally, Wireless sensor network follow the architecture of OSI models and basically has five layers i.e. Application layer, transport layer, Network layer, Data link layer and Physical layer.[4]

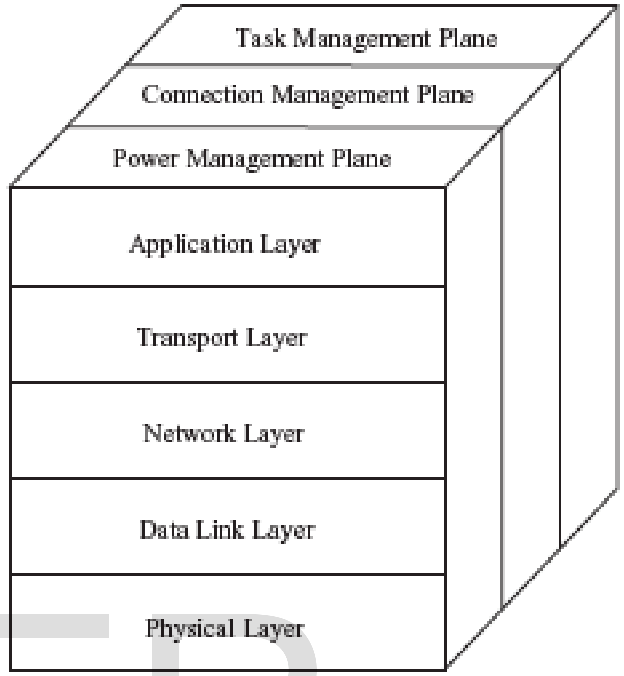


Fig 2: Various layer protocol stack for wireless sensor network.

Application layer is mainly responsible for traffic management and providing modules or software for different applications that translate the data in a reasonable form. [4]

Transport layer provides reliability and congestion avoidance. The transport layer of the Wireless sensor network handles the congestion generated due to the network traffic and the end-to-end reliability of individual packets.

The major function of Network layer is routing. This layer has a lot of challenges depending on the application but apparently, the major challenges are in the power saving, limited memory and buffers.

Data link Layer holds responsible for Data streaming, Data frame Detection, MAC, error control, Data multiplexing and reliability of point to point and point to multipoint data transmission. MAC layer is responsible for Channel access policies, scheduling, buffer management and error control. In WSN we require a MAC protocol to consider energy efficiency, reliability, low access delay and high throughput as major priorities.

Physical layer provides an interface to transmit a stream of bits over physical medium. It is responsible for frequency selection, carrier frequency generation, signal detection, Modulation and data encryption.

In this paper we propose energy efficient clustering and Media access control protocol extend the life span of the nodes and try maintaining energy balance between nodes.

## Network Layer

The sensor nodes due to their small form factor have limited power. In order to prolong the life of the wireless sensor networks, the routing protocols apart from being robust and scalable, needs to be highly energy efficient. A lot of research has taken place in this direction and various routing protocols are proposed to achieve these objectives.

In a fully connected network, all nodes can directly access the base station. However, wireless being a broadcast medium, the congestion in such a network is very high.

Typically, each node in a multi-hop WSN would discover a path to the base station and route its data through this path. This causes the nodes near the base station to be used more frequently than the nodes away from the base station. The is the former set of nodes not only send their own sensed data, but are also responsible for forwarding the packets from the far off nodes in the network. This results in a bottleneck around the base station. If the nodes around the base station go dead, then the nodes away from base station will be unable to send the data unless they increase their transmission ranges.[5]

The network layer is responsible for packet forwarding including routing through intermediate routers, whereas the data link layer is responsible for media access control, flow control and error checking. The major factors affecting network layer protocol are

- Energy Efficiency
- Low computational capacity
- No global ID
- Distributed Computing
- Self organized routing

Due to the above factors energy efficiency in routing algorithm is a major factor to address.

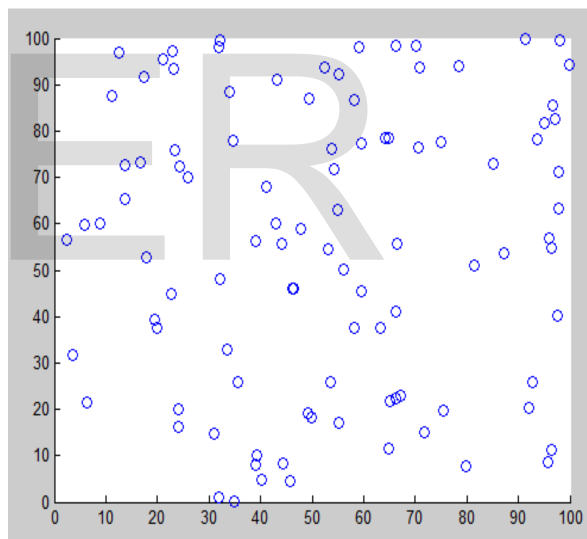


Fig 3: Random positioning of 100 nodes

## LEACH Protocol

LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the

ISSN 2229-5518

cluster heads collective and compact the data and forward it to the base station (sink). Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head.

Nodes that have been cluster heads cannot become cluster heads again for P rounds, where P is the desired proportion of cluster heads. Thereafter, each node has a 1/P probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster.

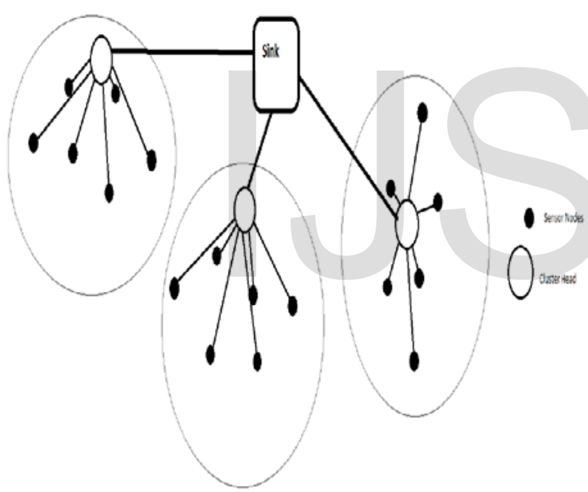


Fig 4: Cluster representation of nodes.

Parameters Selected

| | |
|---|---|
| Dimensions of the area | 100*100m$^2$ |
| Sink in x direction | 50 m |
| Sink in y direction | 175m |
| Number of nodes | 100 |
| Probability of a node becoming a cluster head | 0.05 |
| Packet size | 6400 bits |
| Initial Energy | 0.5J |
| Transmitted Energy | 0.00000005J |
| Received Energy | 0.00000005J |
| Data Aggregation energy | 0.00000005J |

Table 1: Matlab simulation parameters

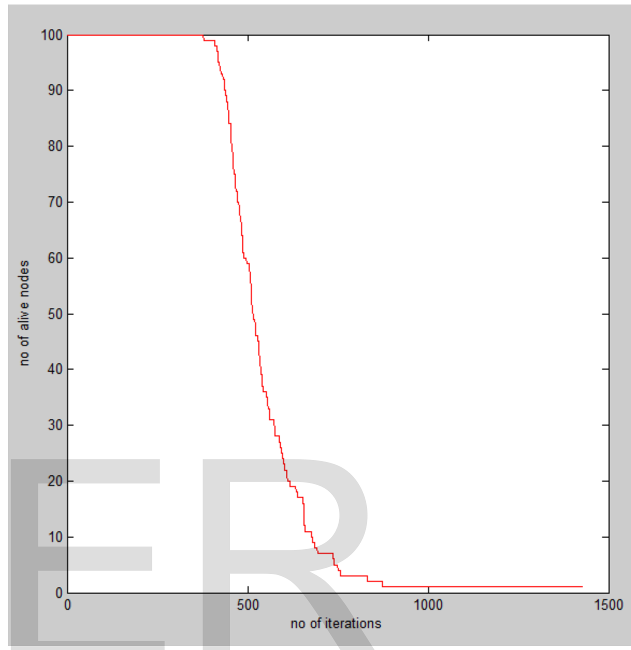


Fig 5: no of iterations vs. no of active nodes

| | |
|---|---|
| Death of first node | 378$^{th}$ iteration |
| Death of 50% of nodes | 515$^{th}$ iteration |
| Death of last node | 1429$^{th}$ iteration |

Table 2: Output parameters

Although LEACH protocol prolongs the network life span in contrast to plane multi-hop routing and static routing, it still has problems. The cluster heads are elected

ISSN 2229-5518

randomly, so the optimal number and distribution of cluster heads cannot be ensured. The nodes with low remnant energy have the same priority to be a cluster head as the node with high remnant energy. Therefore, those nodes with less remaining energy may be chosen as the cluster heads which will result that these nodes may die first. The cluster heads communicate with the base station in single-hop mode which makes LEACH cannot be used in large-scale wireless sensor networks for the limit effective communication range of the sensor nodes.[7]

One of the basic improvements that can be done in leach protocol is to select the nodal probability of becoming a cluster head as

$$P_{ch}=P*E_{node} / Eo$$

In this manner the node with maximum energy would become thee cluster head in the next round and the distance between the sink and the nodal head should be less than the average distance between the nodes and sink, this would help us improve the nodal efficiency by reducing the distance between the nodes while data transmission.

$$D_{ch}<D_{avg}$$

If $P_{ch}<P_{avg}$ and $D_{ch}>D_{avg}$ we would have to select a secondary cluster head so that it would work as a hop to the sink.

If $P_{ch}>P_{avg}$ and $D_{ch}<D_{avg}$ we would not require a secondary cluster head to transmit data to the sink. Re-Clustering of the network should occur when the energy of the cluster head becomes less than the threshold energy $E_{tres}$.

$$E_{tres}=Eo-(N-i)*E_{nc}$$

Where

Eo is the initial energy, $E_{nc}$ is the energy required by a sensor node per cycle, i is the no of cycle and N the number of nodes.

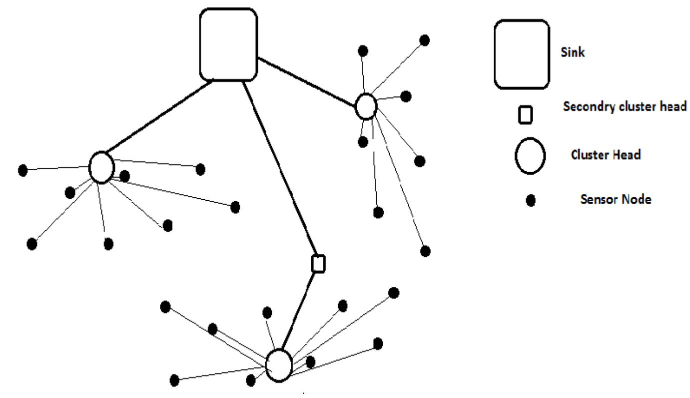


Fig 6: Clustered representation with secondary node

First, a node choose a number between 0 to 1, if the number is less than threshold , then the node becomes cluster head, else, normal nodes it becomes. Cluster heads broadcast their own information to other nodes, the other nodes will listen to the broadcasting messages. All normal nodes determine which cluster they should join in this round based on the strength of the signal they received.

After determining which cluster they should belong, CMAC protocol will be used to send a confirmation message to their cluster heads. At this point, the clusters forming stage is finished.

Each cluster head decides whether to set a secondary cluster head according to the current energy itself and the distance to the base station, if h*ave* $E(i) <E$ or h*ave* $d(i) < d$ , then these kinds of cluster heads should choose the node with maximum energy as secondary cluster head in its cluster, otherwise, the secondary cluster head is not required.[8]

Moreover Leach protocol uses TDMA which increase the energy consumption because of synchronisation and nodes have to be awake during the whole duration of usage. This leads us to the development of new protocol to reduce the above energy loss.

ISSN 2229-5518

**MAC Layer**

Efficient utilization of limited amount of energy has been the key concern in designing MAC protocols for WSNs. As there was a challenge for WSN designers is to develop a system that will run for years, they used not only robust hardware and software, but also lasting energy sources.[9]

In joint channel to control the access of active node, Medium access control (MAC) schemes are used .MAC protocol provides following functions

- Framing: Define the frame format and perform data encapsulation and de encapsulation for communication between devices.
- Medium access: It controls the devices to participate in communication at any time. Medium access becomes a main function of wireless MAC protocols since it broadcasts easily which cause data corruption through collisions.
- Reliability: It ensure successful transmission between devices. Mostly through acknowledgement (ACK) messages and retransmissions when necessary.
- Flow control: From beginning to end prevent frame loss, overloaded recipient buffers.
- Error control: In frames delivered to upper layers, to have power over the amount of errors present it uses error detection or error correction codes.[10]

A good MAC protocol should have the following features:

- Energy Efficiency: Energy efficiency is the first attribute. Battery powered consist in the sensor nodes and it is often extremely complicated to change or recharge batteries for these sensor nodes. Sometimes it is helpful to replace the sensor node rather than recharging them.
- Latency: The second is latency. Latency requirement basically depends on the application. The detected events must be reported to the sink node in real time In the sensor network applications, so that the suitable action could be taken immediately.
- Throughput: With different applications the throughput requirement also varies. A few sensor network application require to sample the information with fine temporal resolution. In such sensor applications it is better that sink node receives more data.
- Fairness: In several sensor network applications when bandwidth is limited, it is compulsory to confirm that the sink node receives information from all sensor nodes fairly. However along with all of the above aspects the energy efficiency and throughput are the key aspects. By minimizing the energy wastage energy efficiency can be increased.[11]

The reasons of wastage of energy in a MAC protocol for wireless sensor networks are as follows

- Collision - Some time the packet gets corrupted during transmission these packets need to be discarded and resent, these lead to increased energy consumption.

ISSN 2229-5518

- Control Packet Overhead - Energy is also required for Sending and receiving control packets due to these less useful data packets can be transmitted.

- Idle Listening - Extra energy is also consumed for Listening to receive possible traffic which is not sent.

- Overhearing - Sometime nodes can pickup which are destined to other nodes. These also leads to unnecessary consume of energy.[12]

**C-MAC protocol**

CMAC is a novel MAC layer protocol; it improves energy efficiency and the latency by utilizing aggressive RTS, Anycast and convergent packet forwarding mechanisms. It uses "aggressive RTS" equipped with double channel check for channel assessment. CMAC there is unsynchronized sleep scheduling (or duty cycling) when there is no packet to transmit. it avoids synchronization overhead during supporting low latency. When there is no traffic, it uses zero communication CMAC allows operation at very low duty cycles.
In the situation of traffic, CMAC first uses anycast for packet forwarding to wake up forwarding nodes or to quickly discover forwarder and then converges from route-suboptimal anycast with unsynchronized duty cycling to route-optimal unicast with synchronized scheduling. For flow initialization it use anycast and for flow stabilization it uses convergent Packet Forwarding the checking of the channel twice to avoid missing activities, time between the two checks should be larger than inter-RTS separation and smaller than RTS duration. Receiver needs to check if co-ordination that channel is busy after waking up. Time between the two checks should be larger than inter-RTS separation and should be smaller than RTS duration [13]

Aggressive RTS-

We propose to use *aggressive RTS* to replace the long preamble, which breaks up the long preamble into multiple RTS packets (also called an *RTS burst*). The RTS packets do not use long preambles, and are separated by fixed short gaps each of which allows receivers to send back CTS packets. Once the transmitter receives CTS, it sends the data packet immediately. Each gap need not accommodate an entire CTS transmission as long as the RTS sender can detect the preamble and cancel the next RTS transmission accordingly. The number of RTS packets to be sent in one RTS burst depends on the duty cycle length. For the same duty cycle length, the duration of one RTS burst is roughly the same as the long preamble used by BMAC. If nodes uniformly randomly wake up during each duty cycle, the expected latency at each hop could be reduced by half.

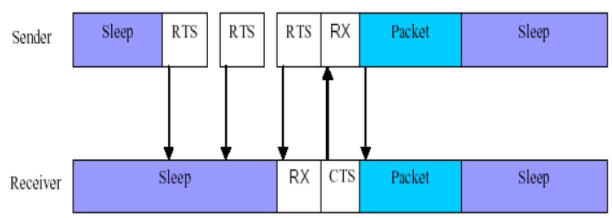


Fig 7: Aggressive RTS in CMAC protocol

To allow nodes to work at a very low duty cycle, nodes must assess the channel very quickly each time they wake up. However, if the receiver wakes up during the gap between two RTS transmissions, it may miss this RTS burst. So we propose to use double channel check which works by assessing the channel twice with a fix short separation between them each time a node wakes up. For each channel check, nodes sample the channel for up to 5 times. Between these two channel checks, the radio could be put to sleep mode to save

ISSN 2229-5518

energy. If the first check detects a busy channel, the second check will be cancelled .Otherwise, the second check is performed. The positive conclusion on busy channel from either check will keep the node awake anticipating an RTS. To prevent the scenario of RTS loss, the interval must be shorter than the RTS transmission time. This can be satisfied by padding RTS packets with extra bytes if needed, that nodes will not miss any nearby RTS burst. [13]

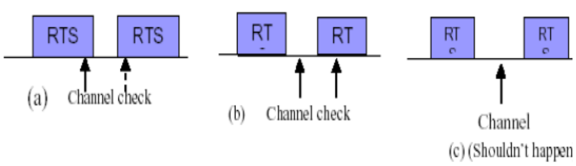


Fig 8: Double channel check in C-MAC protocol

Synchronized Wake-up Schedule -

In order to save more energy after convergence, nodes can synchronize with their neighbor nodes to use some kind of wake-up schedule instead of keeping fully awake. In our simulations, we evaluate a CMAC variant using a staggered scheduling after convergence. When the transmitter intends to converge from anycast to unicast, it synchronizes its schedule with the receiver. The two nodes will maintain the staggered schedule as long as there is traffic between them. After certain duration without traffic, the nodes go back to using unsynchronized duty cycling.



| | |
|---|---|
| Run time | 0.2 sec |
| No of nodes | 20 |
| Net throughport | 10^6 |
| Packet size | 8000bits |
| RTS size | 80bits |
| CTS size | 64bits |
| Acknowledgement size | 64bits |
| Initial energy | 0.5J |
| Energy required to transmit a bit information | 0.00000005J |
| Energy required to recieve a bit information | 0.00000005J |

Table 3: C-MAC Matlab simulation parameters

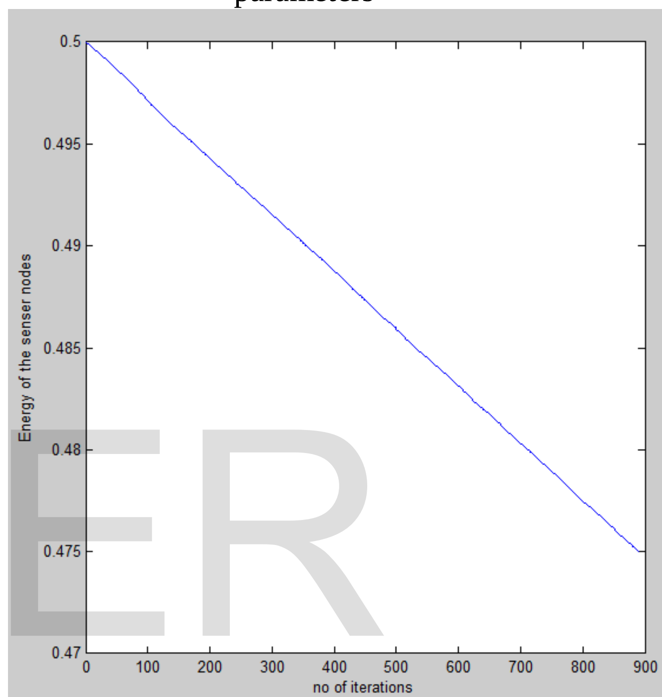


Fig 9: Average nodal energy after every iteration in a round

ISSN 2229-5518

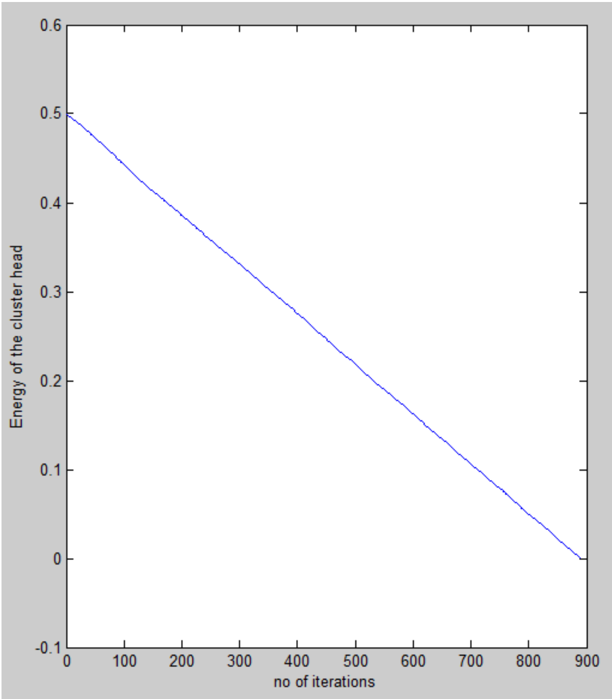


Fig 10: Energy after every iteration in a cluster head

After combining CMAC protocol with Leach protocol energy dissipated due to CMAC protocol was simulated and found to be similar to the below graphs.

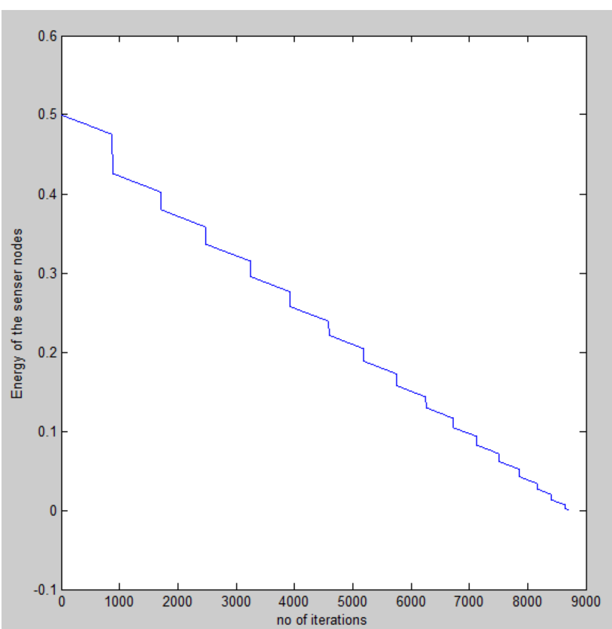


Fig 11: Average energy after every iteration of the sensor nodes

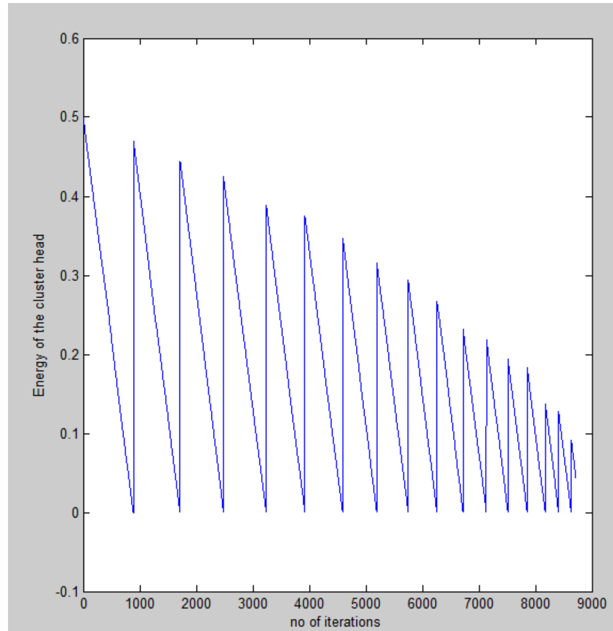


Fig 12: Cluster head energy after every iteration



## Conclusion

Electing cluster head randomly in LEACH protocol causes that the current energy of some cluster heads are less or their distances to base station are far, because of the heavy energy burden, these cluster heads will soon die. A new improved algorithm of LEACH protocol which is aim at balancing energy consumption of the whole network and extending the network lifetime by balancing the energy consumption of these cluster heads.

Existing MAC layer solutions for low duty cycling either consume a lot of energy on periodic synchronization messages or incur high latency due to the lack of synchronization. Thus in this paper we proposes three mechanisms, aggressive RTS, anycast and convergence, to address such problems. We also implement CMAC as the outcome of these three mechanisms above and evaluate it extensively. Hence, we conclude that CMAC is highly suitable for wireless sensor networks that require low latency and high throughput as well as long network lifetime.

Combination of the above protocols would help us obtain a better life span and would give us an energy efficient protocol for wireless sensor network.

**Acknowledgement**

I would sincerely thank Prof. P.C.Jain for his constant guidance and support throughout the research.

I would also like to thank, The Dean of Graduate Studies, SNU for giving us this opportunity to explore in the field of research.

**Reference**

[1]http://en.wikipedia.org/wiki/Wireless_sensor_network

[2]Theses submitted by Jason Lester Hill “System Architecture for Wireless Sensor Networks”, 2003.

[3] Shio Kumar Singh , M P Singh , and D K Singh , Energy Efficient Homogenous Clustering Algorithm for Wireless Sensor Networks,2010.

[4] Ahmad Abed Alhameed Alkhatib, Gurvinder Singh Baicher, Wireless Sensor Network Architecture,2012.

[5] Rakesh Poonia, Amit Kumar Sanghi and Dharm Singh, Energy Efficient Communication Protocols for Wireless Sensor Networks,2011.

[6] Farooq MO, Kunz T, Operating Systems for Wireless Sensor Networks: A Survey, 2011.

[7] Jia Xu,Ning Jin, Xizhong Lou,Ting Peng,Qian Zhou,Yanmin Chen ,“Improvement of LEACH protocol for WSN” 2012.

[8] Chunyao FU, Zhifang JIANG, Wei WEI and Ang WEI,” An Energy Balanced Algorithm of LEACH Protocol in WSN”, 2013.

[9] Bhavana Narain, Anuradha Sharma, Sanjay Kumar and Vinod Patle,” ENERGY EFFICIENT MAC PROTOCOLS FOR WIRELESS SENSOR NETWORKS: A SURVEY”, 2011.

[10]Isha Batra, Dr. Trilok C. Aseri” Comparison of Efficient MAC Protocols for Wireless Sensor Networks”, 2010.

[11] Wei Ye, J.Heidemann and D. Estrin: “Energy- Efficient MAC Protocol for Wireless Sensor Networks”, 2002.

[12] Tijs van Dam and Koen Langendoen. ”An adaptive energy-efficient Mac protocol for wireless sensor networks”, 2003.

[13] Sha Liu, Kai-Wei Fan and Prasun Sinha , “An Energy Efficient MAC Layer Protocol Using Convergent Packet Forwarding for Wireless Sensor Networks”, 2007.