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# LEACH: ANALYSIS OF WIRELESS SENSOR NETWORK PROTOCOL

***Ankit Pare***
***PG Scholar,***
***Computer Science Engineering,***
***Jawaharlal Institute of Technology,***
***Borawan, Khargone, MP, India***

***Ankit Dongre***
***Computer Science Engineering,***
***Jawaharlal Institute of Technology,***
***Borawan, Khargone, MP, India***

***Abstract— This paper studies LEACH protocol, some of its modified versions and finally puts forward a new version of LEACH called Energy Efficient Extended LEACH (EEE LEACH) protocol. This new version of LEACH protocol establishes multilevel clustering approach to minimize communication distance between nodes and introduces Master Cluster Heads along with Cluster Heads. Simulation has been done in MATLAB and simulation results show that EEE LEACH is more energy-efficient than LEACH protocol.***

**Keywords—** ***LEACH, Extended LEACH, Energy, and Cluster.***

## I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of a large number of tiny nodes with sensing, computation, and wireless communications capabilities [1]. The sensors attached to the nodes measure ambient conditions related to the environment in which they are deployed, process the data and transmit them to the base station. Besides, sensor nodes are equipped with a radio transceiver or other wireless communications device, a small microcontroller and an energy source. Since in most WSN applications the energy source is a battery [4] and energy plays an important role in such applications because sensor nodes are generally constrained with limited energy. Therefore, preserving the consumed energy of each node is an important goal that must be considered when developing a routing protocol for WSN. In general, routing in WSNs [3] can be divided into flat, hierarchical, and location based routing depending on the network structure. Hierarchical routing is also known as cluster based routing because in this type of routing sensor nodes are grouped together and form clusters. In each cluster, a higher energy node is assigned as a head-node and known as cluster-head (CH). The CH acts as the leader of their own cluster having the responsibilities like collection and aggregation the data from their respective clusters and transmitting the aggregated data to the Base station (BS) [5] [18].

The most well-known hierarchical routing protocols in WSN are LEACH, PEGASIS, TEEN, EECS, HEED etc [13]. Among these all, LEACH is the simplest routing protocol in WSN whose main aim is to distribute the energy load equally among all sensor nodes in the network and prolong network life time. In this paper we propose an improved version of LEACH protocol which is more energy efficient by taking less radio communication distance than original LEACH.

In section 2 we discuss the detailed description of LEACH protocol and some of its modified versions. In Section 3 we introduce our proposed protocol. Section 4 represents the implementation details, in section 5 Ease of Use

## II. DESCRIPTION OF LEACH PROTOCOL

LEACH stands for Low-Energy Adaptive Clustering Hierarchy and it was one of the first cluster-based hierarchical protocols [1].In this protocol, the sensor nodes are combined together and form a local cluster. Among all sensor nodes one node acts as a CH inside from the local cluster. A randomize rotation technique of CH is used by this protocol whose main aim is to distribute the energy load equally among all sensors in the network which ultimately gives result of a longer life to the node's battery [5]. The major role of CH is to collect data from their respective cluster and aggregate those collected data and finally sent to the base station. In this manner, LEACH enables scalability and robustness for dynamic networks, and incorporates data fusion into the data gathering process to reduce the amount of data to be transmitted [6].

The Operation of LEACH is divided into two phases and these phases are further divided in some sub-phases. Each LEACH round begins with a set-up phase and a steady-state phase. In set-up phase cluster heads are randomly chosen and cluster are organized as shown in the following figure. In steady-state phase nodes transmit their data to their respective CHs, and after that the CHs transmit the whole cluster "compressed" data to the base station [6]. The timeline diagram that includes both two phases for a single round of LEACH is given below [2].

The following sub-phases are included in the above mentioned two phases to complete the LEACH operation [16]. They are:

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Advertisement Phase, Cluster Set-Up Phase, Schedule Creation Phase (come under Set-up phase) and Data Transmission Phase (come under steady-state phase)[6].

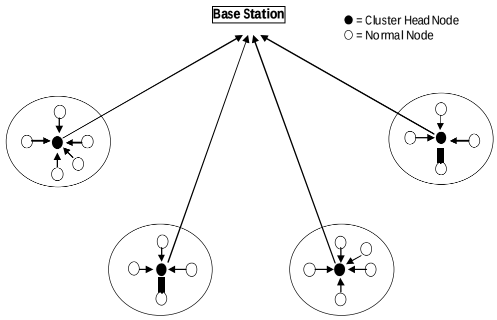


*Fig 1 : Clusters Organization in LEACH Protocol*

### *2.1 Phases Description*

#### *Advertisement Phase*

It is the first step of the set-up phase. Here the decision of each node to elevate as a CH is made for the current round. This decision is made by the n node by choosing a random number r between 0 and 1[6]. The node becomes a CH if the randomly obtained value is less than a threshold T(n) which is calculated by the following formula [3] [13] [16] [17].

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(r \bmod \frac{1}{P}\right)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where,

n = given number of nodes.

p = the priori probability of a node being elected as a CH.

r = a random number between 0 and 1 that is selected by a sensor node. If this random number is less than the threshold value T (n), then the respective node becomes the CH for the current round.

G = the set of nodes that were not accepted as CH in the last “1/p “events.

Now each nominated CH starts advertise their own status to the rest of the nodes in the network. The noncluster-head nodes must keep their receivers on during this phase to hear the advertisements of all the CH nodes [16] [17].

#### *Cluster Set-Up Phase*

After receiving this advertisement message the noncluster-head nodes decide suitable cluster for them. They will choose the CH which sent the message with the largest signal strength heard [14]. This fact means the election of the CH to whom the minimum amount of transmitted energy is needed for communication [6]. When the noncluster-head nodes take this decision, then they will inform their respective CH by a message using CSMA MAC protocol that they want to be member of the cluster.

#### *Schedule Creation Phase*

After receiving all messages from the non-cluster head nodes, each cluster head include them to their respective cluster. For each node the CH creates TDMA schedule which indicate that they can transmit data.

#### *Data Transmission Phase*

When the TDMA schedule is fixed for each node, then according to the allocated schedule each node can transmit data to their respective CH. The C nodes must keep its receiver on to receive all the data from the nodes in the cluster [6]. When they receive all the data from the nodes, they perform aggregation mechanism to compress the amount of data, and next this data is sent to the base station.

After a certain time, a new round begins with the Advertisement Phase

### *2.2 Drawbacks of LEACH*

LEACH is the simplest hierarchical protocol which possesses clustering approach and if implemented properly, can lead to energy efficient networking in WSNs [18] [14]. But still these significant energy savings, there raises some issues as described below:

- LEACH is suitable for small size network because in LEACH it assumes that all nodes can communicate with each other and are able to reach sink which is not always true for large size network [1].
- LEACH provides time slots for each node in the network to transmit data to CHs even though some nodes might not have data to transmit [3] [15].
- LEACH requires that all nodes are continuously listening which is not realistic in a random distribution of the sensor nodes [3] [19].
- In LEACH there is no mechanism to ensure that the elected CHs will be uniformly distributed over the network. So all cluster-heads might be concentrate only in one part of the network [17].
- In LEACH periodic dynamic clustering occurs after the completion of each round that carries significant overhead which may balance energygain derived by the clustering option [3] [19].



*Corresponding Author: Ankit Pare, Jawaharlal Institute of Technology, Khargone, MP, India.* 

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Since LEACH has many drawbacks, many researchers have been done to make this protocol performs better. Some of these advancements are briefly described in the following points.

### *2.3 Advancements in Different types of LEACH*

***LEACH-F***

It is the modified version of LEACH protocol with fixed clusters and rotating cluster heads [7]. Here clusters are formed once and fixed, and the cluster-head's position rotates among the nodes within the cluster. As clusters are formed only once so there is no set-up overhead at the beginning of each round. LEACH-F does not allow new nodes to be added to the system and do not adjust their behavior based on nodes dying.

***LEACH-C***

W. B. Heinzelman et al. proposed application specific protocol architecture for WSN which is known as LEACH Centralized (LEACH-C) [8]. it is an enhancement over the LEACH protocol. LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH-C is more efficient than LEACH because LEACH-C delivers about 40% more data per unit energy than LEACH.

***E-LEACH***

Energy-LEACH (E-LEACH) [9] improves the CH selection procedure in LEACH. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round. The operation of E-LEACH is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy.

***V-LEACH***

V-LEACH [10] is a new version of LEACH Protocol which aims to reduce energy consumption within the wireless network. The main concept behind V-LEACH is that besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies which will extend the overall network life time.

***H-LEACH***

Hierarchical LEACH (H-LEACH) [3] is proposed by Wairagu G. Richard considering the concept by minimizing the communication distance between nodes to conserve energy. It employs the same clustering approach as LEACH during initial phases and later it extends LEACH by further clustering the cluster heads and nominates one of the cluster head, which then acts as the Master Cluster Head (MCH), to forward data to the base station. In H-LEACH finally only one MCH is involved to transmit all compressed data to base station, so central point of failure situation may occur when the MCH will be dead.

## III. PROPOSED PROTOCOL

A lot of simulation works / experiments are going on in the research field of WSN to make routing protocols more and more energy efficient. In this paper, we propose a modified version of LEACH called EEE LEACH that can increase energy efficiency than original LEACH. The basic concept involved in increasing energy efficiency is to keep radio communication distance as possible as minimum [3]. The popular technique used to minimize communication distance is the formation of clusters between nodes rather than direct communication [3] [15].

The more we increase the number of clusters, the more communication distance decreases and as a result energy efficiency of the protocol increases. So, we can say that the number of clusters and communication distance are inversely proportional to each other. Keeping these concepts in mind, we proposed multilevel clustering technique in our proposed protocol. Here besides having a single layer of clusters formation between the nodes and Base station like LEACH, it involves two layers of clusters formation. In the first layer CHs are formed where the normal nodes transmit their own data to their respective CH and by using the data aggregation energy (EDA) technique, CHs aggregate the received data. Again in the second layer Master Cluster Heads (MCH) are formed. After the formation of MCHs, the CHs search the nearest MCHs by calculating the distance between them and transmit their aggregate data to the respective MCHs. In the similar way, the MCHs receives data from their nearest CHs, aggregate all received data by using their master data aggregation energy ($E_{MDA}$) technique, transform them into a compress format and forward them to the base station (BS).

The number of CHs and MCHs are initially decided by using a predetermined fractional value say (5% to 30%) for CHs and (2% to 15%) for MCHs. In EEE LEACH, we keep the number of MCHs less than the number of CHs to minimize the overall communication distance between the nodes and Base station.
The key idea of introducing both CHs and MCHs in our new version of LEACH protocol is to minimizes the control overhead on CHs and distribute the load equally among the MCHs while finally forward data to BS. This will overcome



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the situation of node failure when nodes suffer from extra overhead.

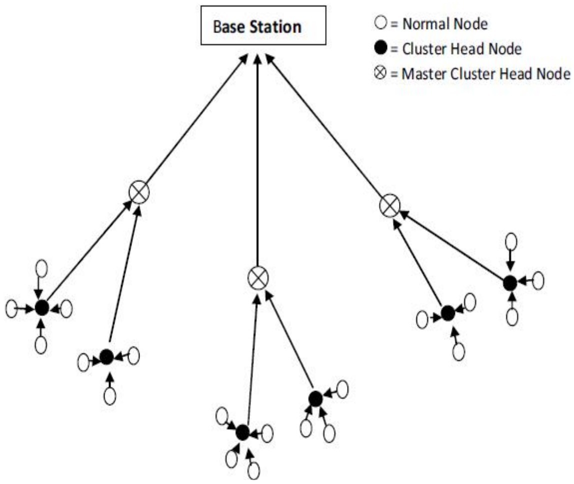


*Fig 2 : Clusters Organisation in EEE-LEACH Protocol*

*A. Radio Communication Distance*

Let the distance from the sensor field to the base station be x, distance between nodes be y, distance between CHs is z, the number of normal nodes is n1, the number of CHs is n2, and the number of MCHs is n3 [3]. The radio communication distance of an existing LEACH model is calculated by using the following formule [3]:

$$d = (n1 * y) + (n2 * x) \quad (2)$$

For example, Let there are total 200 nodes in both existing LEACH and proposed EEE LEACH. Using LEACH algorithm, the nodes are grouped into 34 numbers of clusters. Therefore the numbers of CHs are 34 and normal nodes are 166.

Similarly let, using EEE LEACH algorithm 200 nodes are divided into 30 numbers of CHs, 4 numbers of MCHs and 166 numbers of normal nodes. The above formula (2) can be modified for proposed
EEE LEACH model as follows:

$$d' = (n1 * y) + (n2 * z) + (n3 * x) \quad (3)$$

Let, x=15, y=2, z=3

Now in LEACH, d = 166*y + 34*x = 842 unit.

And in EEE LEACH, d' = 166*y + 30*z + 4*x = 482 unit.

In this way we can observe that there is huge difference between d and d' as d' is very minimum in comparison of d. Thus, multilevel clustering greatly minimizes transmission distances which in turn conserve energy consumption.

## IV. IMPLEMENTATION DETAIL

The routing protocols LEACH and EEE LEACH have been simulated accurately in MATLAB. These have been made assuming a network having dimensions 200 x 300 meters. The number of nodes in each protocol is assumed to be 200. The nodes are generated and placed randomly. The energy-awareness of each routing protocol is evaluated with respect to the following parameters:

- The energy consumption by nodes in each round.
- The number of rounds required for a certain percentage (0.5%, 50%, and 100%) of the nodes to become dead.
- The optimal election probability value of Cluster Head's (p) and Master Cluster Head's (pm) to determine the greater efficiency of the proposed protocol.

The equations governing the transmission cost and receiving costs for a k-bit message and a distance d are as follows [2] [12] [16] [18]: Energy consumption of transmitting data(ETX) in case of multipath fading and free space are given as:

$$E_{TX}(k,d) = E_{TX} - \{ (E_{elec} * k) + (E_{mp} * k * d4)\} \quad (4)$$

$$E_{TX}(k,d) = E_{TX} - \{ (E_{elec} * k) + (E_{fs} * k * d2)\} \quad (5)$$

Energy consumption of receiving data ($E_{RX}$) is given as:

$$E_{RX}(k) = E_{RX} - ( E_{elec} + E_{DA} ) * k \quad (6)$$

Where,

$E_{elec}$ denotes amount of Energy consumption per bit in the transmitter or receiver circuitry.

$E_{mp}$ Amount of energy consumption for multipath fading.

$E_{fs}$ Amount of energy consumption for free space. \

For each node in the protocol an initial energy is given say E0 and after the completion of each round, energy is consumed by the protocol and E0 starts decreasing. In this way when the E0 of any one of the nodes in the protocol becomes zero then the first-node-dead situation occurs.

Similarly when the E0 of the half number of nodes in the protocol becomes zero then half-node-dead situation occurs and when the E0 of the last number of nodes in the protocol becomes zero then the last-node-dead situation occurs.

The number of CHs and MCHs are determined by fixing the p and pm value in equation 1 which gives the threshold value T first and based on the value of T, we get the number of CHs and MCHs. To determine the number of MCHs, we put the pre-determine fixed value of pm at the place of p in equation 1 and calculate T and then we get number of MCHs.

The parameters involved in simulation are described in the following table I.

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***TABLE I. Simulation Parameter***

| S. No. | *Simulation Parameters and their Values* | |
|---|---|---|
| | ***Parameters*** | ***Value*** |
| 1 | Routing Protocols | LEACH, EEE LEACH |
| 2 | Environment Size | 200 x 300 |
| 3 | Number of nodes | 200 |
| 4 | Packet Size | 2000 bits |
| 5 | Election Probability value of CHs (p) | 10% to 30% |
| 6 | Election Probability value of MCHs(pm) | 2% to 15% |
| 7 | Number of rounds | 5 to 10,000 rounds |
| 8 | Initial energy per node (E0) | 1 J |
| 9 | Total energy of the network system | 200 J |
| 10 | $E_{elec}$ | 50 nJ / bit |
| 11 | $E_{fs}$ | 10 pJ / bit / m2 |
| 12 | $E_{mp}$ | 0.0015 pJ / bit / m4 |
| 13 | $E_{DA}$ | 5 nJ / bit |
| 14 | $E_{MDA}$ | 3 nJ / bit |

***4.1 Snapshot of the Routing Protocol's in MATLAB***

The simulated output of LEACH and EEE LEACH protocols in MATLAB are shown in Fig 3 and 4 respectively

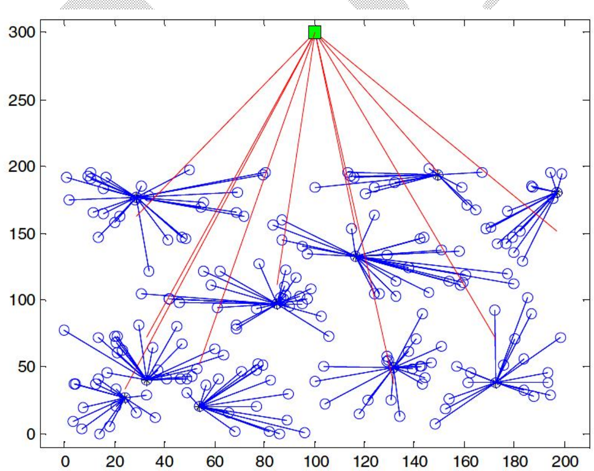

**Fig 3 : LEACH Protocol**

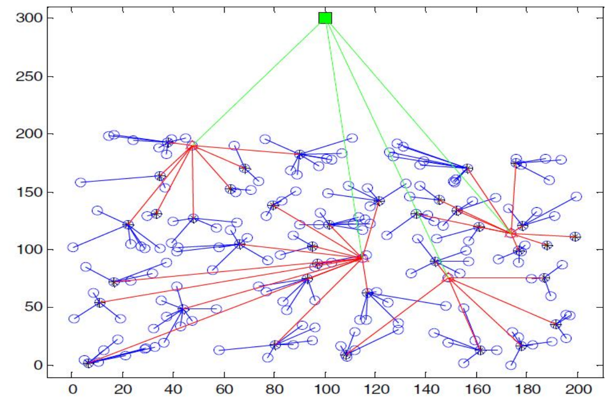

***Fig 4 : EEE LEACH Protocol***

## V. RESULTS AND DISCUSSION

We simulated our proposed protocol and compared the generated data with the original LEACH protocol. Fig 4 shows the comparison graph between LEACH and EEE LEACH in terms of consume energy after the completion of 5th round. At this time the amount of consume energy in LEACH is 1.5758 J and in EEE LEACH is 0.4223 J at p=15% in both protocols and at pm=2% in EEE LEACH. From the graph it is clearly understood that EEE LEACH is more energy efficient than LEACH since EEE LEACH consumes less energy than LEACH.

Fig 6 shows the first node dead graph between LEACH and EEE LEACH for 50, 100, 150 and 200 number of nodes in terms of rounds. For 50 number of nodes, the first node in LEACH and EEE LEACH was dead in 307 and 653 number of rounds respectively Similarly in case of 100, 150 and 200 number of nodes , the first node in LEACH and EEE LEACH was dead in [355 and 735], [371 and 747] and [392 and 799] number of rounds respectively. The procedure to find the first node dead is mentioned in the above implementation details section. Therefore it is clearly shown that in case of EEE LEACH the first node died later than in LEACH.

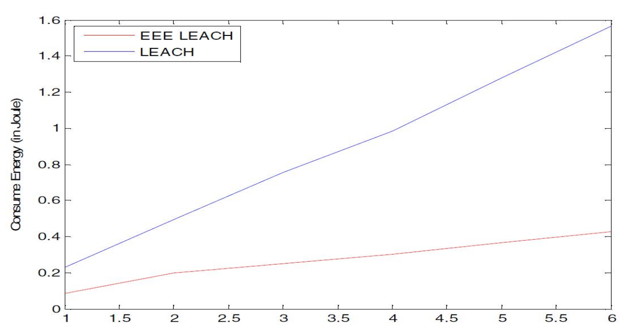


***Fig 5 : Consume Energy graph of EEE LEACH and LEACH***



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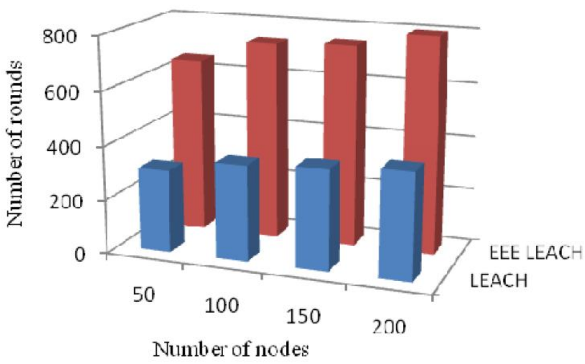


*Fig 6 : Graph of first node dead in EEE LEACH and LEACH*

Fig 7 shows the half number of node dead (50%) graph between LEACH and EEE LEACH for 50, 100, 150 and 200 number of nodes in terms of rounds. For 50 number of nodes, the half number of nodes in LEACH and EEE LEACH were dead in 961 and 1493 number of rounds respectively Similarly incase of 100, 150 and 200 number of nodes , the half number of nodes in LEACH and EEE LEACH were dead in [1180 and 2017], [1312 and 2132]

Fig 8 shows the last node dead (100%) graph between LEACH and EEE LEACH for 50, 100, 150 and 200 number of nodes in terms of rounds. For 50 number of nodes, the last node

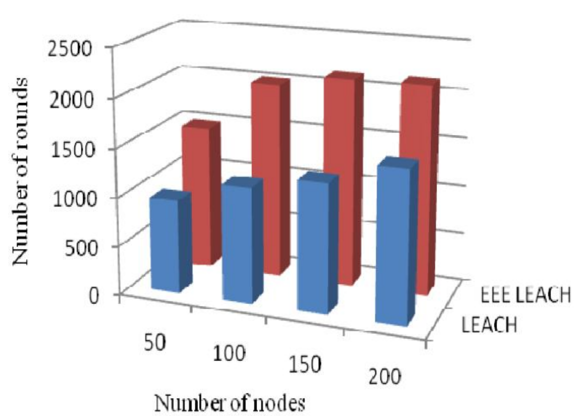


*Fig 7 : Graph of half node dead in EEE LEACH and LEACH*

in LEACH and EEE LEACH was dead in 4592 and 5094 number of rounds respectively Similarly incase of 100, 150 and 200 number of nodes , the last node in LEACH and EEE LEACH was dead in [4732 and 5174], [5310 and 5503] and [6427 and 7142] number of rounds respectively. The procedure to find the last node dead is mentioned in the implementation details section as well. Therefore it is clearly shown that in case of EEE LEACH the last node died later than in LEACH.

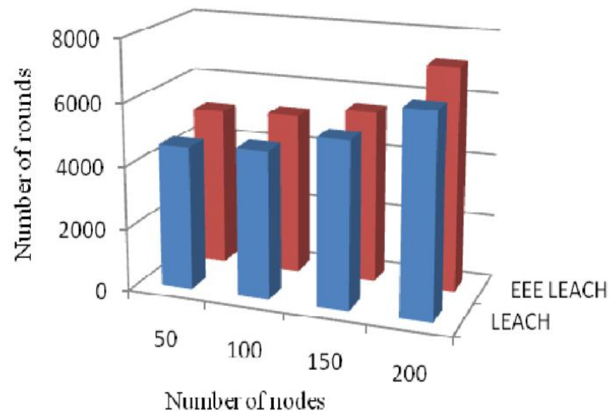


*Fig 8: Graph of last node dead in EEE LEACH and LEACH*

Overall from each of these three graphs it is clear that in EEE LEACH nodes survive longer than in LEACH. Thus EEE LEACH prolong network lifetime than LEACH. Figure 10 represents the graph between LEACH and EEE LEACH with fixing the cluster head election probability (p) value from 5% to 30% in both protocols and vary the Master cluster head election probability (pm) value at 2%, 4%, 6%, 8% and 10% respectfully for EEE LEACH protocol. This probability values p and pm also affect the threshold value in equation 1. The graph shows that the remaining energy of EEE LEACH protocol at pm = 2%

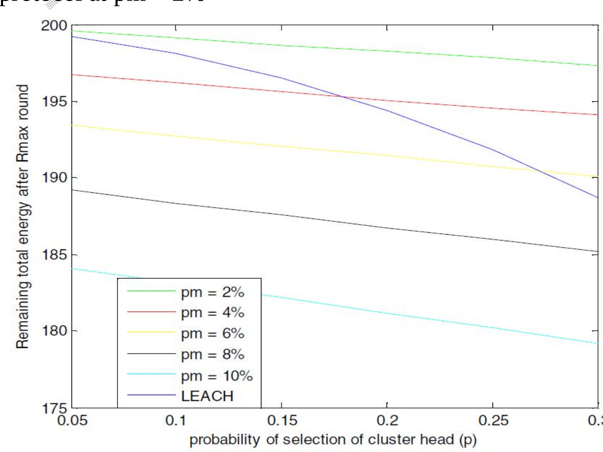


***Fig 9 : Comparison graph between EEE LEACH and LEACH with various pm values at same p values***

Fig 9 represents the graph between LEACH and EEE LEACH with fixing the cluster head election probability (p) value from 5% to 30% in both protocols and vary the Master cluster head election probability (pm) value at 2%, 4%, 6%, 8% and 10% respectfully for EEE LEACH protocol. This probability values

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p and pm also affect the threshold value in equation 1. The graph shows that the remaining energy of EEE LEACH protocol at pm = 2%.

Gradually when the pm value increases in EEE LEACH then for less p value EEE LEACH becomes less efficient than LEACH but at a greater p value, again EEE LEACH becomes efficient than LEACH. Overall EEE LEACH performs better at low pm value and to perform in a same way with increasing pm values, its p value should also increase.

## VI. CONCLUSIONS

In this paper we considered a well-known wireless sensor network routing protocol called LEACH and proposed a new version of LEACH protocol called EEE LEACH. Then EEE LEACH protocol is successfully simulated and compared with LEACH protocol. From the simulation results we can draw the conclusion that EEE LEACH is more energy-efficient than LEACH with greater network lifetime.

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