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Improved Cluster Head Selection Using Enhanced LEACH Protocol

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***Abstract*— Routing in Wireless Sensor Network (WSN) is an important area of research due to its rapidly increasing application in monitoring various kinds of environment by sensing physical phenomenon. It introduces an energy efficient clustering algorithm for WSN based on Low Energy Adaptive Clustering Hierarchy (LEACH) which will remove some of the drawbacks of LEACH. It utilizes the remaining energy of the current Cluster Head (CH) to make the routing process more efficient. In heterogeneous sensor networks, some nodes become cluster heads which aggregate the data of their cluster nodes and transmit it to the sink. Improved hierarchical clustered heterogeneous network has been proposed where the advanced nodes elect themselves as cluster heads for the increasing number of rounds based on their higher initial energy relative to other nodes. Proposed algorithm is designed and implemented in MATLAB. It is shown that the proposed algorithm provides better results than existing, as we have extended the stability time or when the first node dead time. Also last node dead or network lifetime is also increased. Proposed algorithm has also increased the throughput of the wireless sensor network.**

***Index Terms*—WSN, Advance Nodes, Energy Consumption, Dead Nodes**

I. INTRODUCTION

A wireless sensor network consists of a large number of sensor nodes and a base station that serves as a gateway to some other networks. Sensor node senses their environment, collect sensed data and transmit to the base station. It is a network which is wireless and deals with sensors. It consists of nodes that communicates with each other through wireless links sensors that are remotely deployed in large numbers and operates environments. A Wireless Sensor Networks (WSN) includes spatially distributed sensors to cooperatively monitor various environmental conditions, which includes temperature, sound, vibration, pressure, motion or pollutants. It consists of a large number of nodes with a limited energy supply. Wireless Sensor Network (WSN) is an advanced intelligent network which is organized by amounts of functional sensor nodes. The sensor nodes in Wireless Sensor Network can transmit information and cooperate with each other to accomplish some special functions through implementing the self-organization wireless communication manner. In addition, Wireless Sensor Network can be widely applied in the following areas, such as military, industry, agriculture, medical and environmental monitoring area [6] .To reduce the consumption of energy, the network routing protocol is regarded as a new direction being researched for the energy-constrained wireless sensor network. As a result, the routing protocol can reduce communication volume and save network energy. Low Energy Adaptive Clustering Hierarchy (LEACH) is the first implemented cluster-based routing protocol and it is also considered as the base of other cluster routing protocols.

II. VARIOUS HIERARCHICAL ROUTING PROTOCOLS

The main objective of hierarchical routing is to maintain the energy consumption of various sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head. LEACH is one of the first hierarchical routing approaches for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed. We explore hierarchical routing protocols in this section.

A. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network which partitions the nodes into clusters, in each cluster a dedicated node with extra privileges called Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS where these data is needed using CDMA (Code division multiple access**)**. Remaining nodes are cluster members [8].

Architecture of LEACH

The operation of LEACH protocol is broken into rounds. Each round begins with setup phase, during which clusters formation takes place and steady phase during which data is being transferred to base station. Steady phase is usually longer than set up phase. Initially at the beginning of each round, each node decides whether it has to be CH or not. The node which decides to be cluster head sends a message. All other nodes other than the CH will keep their receiver on and decide to which CH they need to join [3]. Every node selects a cluster head which is close to it. All nodes send messages to their respective cluster heads. The CH based on the number of requesting node creates a proper TDMA schedule for all the nodes. Only during their respective schedules nodes interact with the CH, else the nodes will go to sleep mode. The cluster heads obtains data from all nodes in its cluster, further aggregates the data and finally sends it to the base station. The phase after the schedule has been announced, is called the steady phase and phase before schedule is announced, is referred as setup phase. After the steady phase next round start Each node independent of other nodes decides whether it will selected as a CH or not. This decision made takes into account when the node served as a CH for the last time (the node that has not been a CH for long time has more probability to elect itself than nodes that has been a CH recently) [6]. In the following advertisement phase, the CHs inform their neighborhood with an advertisement packet that they become CHs. Non-CH nodes pick the advertisement packet with the strongest received signal strength. In the next cluster setup phase, the member nodes inform the CH that they become a member to that cluster with "join packet" contains their IDs using CSMA. After the cluster-setup sub phase, the CH knows the number of member nodes and their IDs [6]. Based on all messages received within the cluster, the CH creates a TDMA schedule, pick a CSMA code randomly, and broadcast the TDMA table to cluster members. After that steady-state phase begins.

B. Energy-LEACH protocol

Our energy-LEACH protocol improves the cluster head selection procedure. It makes residual energy of node as the main matrix which decides whether these nodes turn into cluster head or not in the next round. In first round communication, every node has the same probability to turn into cluster head. n (n=p×N) nodes are randomly selected as cluster heads, and then, the residual energy of each node is different after one round communication. We select n nodes with more residual energy as cluster heads in next round communication, and so on until all nodes are dead. Same as the LEACH protocol, energy-LEACH protocol also divides into many rounds, and each round contains cluster formation phase and cluster steady phase.

- In cluster formation phase, each node decides whether to turn into cluster head or not by comparing with residual energy
- Some nodes with more residual energy turn into cluster heads and send cluster head information to inform other nodes. The other nodes with less residual energy turn into common nodes, and send information about joining cluster to a cluster head

In cluster steady phase, nodes in a cluster send data according to TDMA table, and cluster heads receive, fuse and send data to sink. After a period of time, the network reforms the cluster head selection procedure in a new round. In cluster formation phase, the flow chart of whether a node turns into cluster head or a common node

III. EXPERIMETAL SET UP

In this work, the authors assumed a hierarchical clustered heterogeneous sensor network with 100 sensor nodes which are randomly distributed over the 100×100 m^2 area. The sink or base station is located at point (50×50). The packet size that the nodes send to their cluster heads as well as the aggregated packet size that a cluster head sends to the sink is set to 4000 bits. The initial energy of each normal node is set to 0.5 Joule. The proposed approach has been implemented in MATLAB and the performance has been evaluated by simulation. In this work, we have measured the lifetime of the network in terms of rounds when the first sensor node dies. All the parameter values including the first order radio model characteristic parameters are mentioned in the Table 1 below:

Table 1. Various parameters and their values

PARAMETERS	VALUES
Sensor field	100×100
Sink position	50×50
N	100
M	0.3
Packet size	4000
Efs	10pJ/bit/m^2
Emp	0.0013pJ/bit/m^4
E_{DA}	50nJ/bit
E_O	0.5 J
P	0.1
A	4

IV. HETEROGENEOUS WSN MODEL

In this section, the authors describe the heterogeneous wireless sensor network model which includes cluster formation and maintaining optimum number of clusters.

A. Creation of a cluster

In our work, we have considered a hierarchical clustered network. The Low Energy Adaptive Clustering Hierarchy (LEACH) is a protocol which is hierarchically clustered where clusters are re-established in each round. In this protocol, new cluster heads get elected in each round and as a result the load becomes well distributed and balanced among the nodes of the network. An optimal percentage of nodes p_{opt} is considered that has to become cluster head in each round [8].We have assumed the same distributed algorithms to form clusters in the network. To decide whether a node to become cluster head or not a threshold T(s) is addressed in which is as follows:

$$T(S_{(nrm)}) = \begin{cases} \dfrac{P_{nrm}}{1 - P_{nrm}\left(r.mod.\dfrac{1}{P_{nrm}}\right)}, & if\ s \in G \\ 0 & otherwise \end{cases} \quad (1)$$

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Where r is the current round number and G is the set of nodes that have not become cluster head within the last $1/p_{opt}$ rounds. At the beginning of each round, each node which belongs to the set G selects a random number 0 or 1. If the random number is less than the threshold T(s) then the node becomes a cluster head in the current round [8].

B. Optimum number of clusters

According to the radio energy model addressed in [7], in order to achieve an acceptable SNR in transmitting an L bit message over a distance d, the energy dissipated by the radio is given by:

$$E_{Tx}(l.d) = \begin{cases} L.E_{Elec} + L.\epsilon_{fs}.d^2, & if\ d \le d_0 \\ L.E_{Elec} + L.\epsilon_{mp}.d^4, & if\ d \ge d_0 \end{cases} \quad (2)$$

Where E_{Elec} is the energy dissipated per bit to run the transmitter or receiver circuit, (ϵ_{fs} free space fading) and ϵ_{mp} (multi path fading) are the energy expenditure of transmitting one bit data to achieve an acceptable bit error rate and d is the distance between a cluster member node and its cluster head. By equating the two expressions at d = d_0, we get

$$d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \quad (3)$$

So according to [2], the optimum number of clusters k_{opt} for our cluster based network, having n sensor nodes distributed randomly in a (MxM) sensor field is as follows:

$$k_{opt} = \sqrt{\frac{n}{2\pi}}.\sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}.\frac{M}{d^2} \quad (4)$$

Again, the optimal probability of a sensor node to become cluster head can be calculated as:

$$P_{opt} = \frac{k_{opt}}{n} \quad (5)$$

V. PROPOSED PROTOCOL

In this work, we have analyzed a heterogeneous sensor network environment. Where p is the percentage of advance and normal nodes having 'a' times more energy than the normal nodes that are distributed randomly over the sensor field. A cluster head election process is considered based on the battery power and residual energy of the node. In our approach, advanced nodes have higher probabilities to become a cluster head in a particular round than the normal nodes. The proposed heterogeneous network model doesn't effect on the spatial density of the network but changes the total initial energy of the network. We have individual initial energy equations for normal and advanced nodes as follows:

$$E_1 = E_0.(1 + a) \quad (6)$$

Where, E_0=Energy of a normal node

E_1=Energy of an advanced node

$$E_t = n.E_0.(1 - p - k) + n.p.E_0.(1 + a)$$

$$E_t = n.E_0.(1 + p.a) \quad (7)$$

In this work, we have approached to assign a weight to the optimal probability of a sensor node to become cluster head in a particular round. This weight must be equal to the division of the initial energy of each node by the initial energy of a normal node. If all the nodes are homogeneous, all the nodes will become cluster head once every 1/ p_{opt} round which is coined as epoch of the network. In our approach the average number of cluster heads per round per epoch is equal to n.(1+p.a). The weighted election probabilities for normal and advanced nodes are defined. In our scenario, the weighted election probabilities for the normal and advanced nodes are as follows:

$$P_{nrm} = \frac{p_{opt}}{1+p.a} \quad (8)$$

$$P_{adv} = \frac{p_{opt}}{1+p.a+}.(1 + a) \quad (9)$$

We further define the thresholds T(s_{nrm}), T(s_{adv}),) for the normal, advanced nodes. In equation (1) we have replaced p_{opt} by the weighted probabilities of normal and advanced nodes to obtain the threshold that is used to elect the cluster head in each round. Thus, the threshold for the normal nodes to become cluster head can be evaluated by the following equation:

$$T(S_{(nrm)}) = \begin{cases} \frac{P_{nrm}}{1-P_{nrm}.\left(r.mod.\frac{1}{P_{nrm}}\right)}, & if\ s \in G \\ 0 & otherwise \end{cases} \quad (10)$$

Where r is the current round number, G' is the set of normal nodes that have not become cluster head within the last $1/p_{nrm}$ rounds of the epoch. T(s_{nrm}),is the threshold applied to a population of n.(1-p-k) that are normal nodes. This ensures that each normal node will become a cluster head exactly once every (1+p.a+k.b)/ p_{nrm} rounds per epoch .

VI. PERFORMANCE ANALYSIS

A. WSN in active stage

Figure 1 is showing the WSN in active mode where all nodes are active. As it is Leach so all nodes represented by circles are normal nodes and nodes with circle and star (*) are cluster heads.

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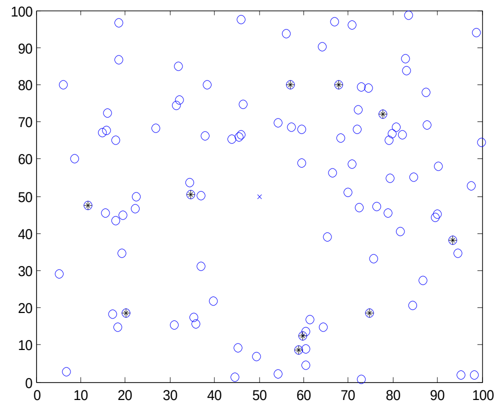

Fig 1 Initial configuration in LEACH

Figure 2 is showing the WSN in active mode where all nodes are active. As it is Energy Leach so all nodes represented by circles are normal nodes and all nodes represented by plus (+) are advance nodes and with star(*) are cluster heads.

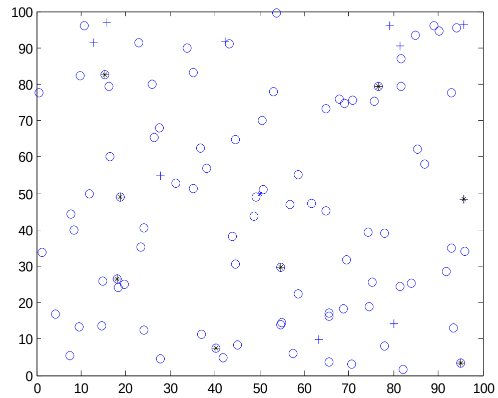

Fig 2 Initial configuration in Energy LEACH

Figure 3 is showing the WSN in active mode in Proposed Leach where all nodes are active. As it is Improved Energy Leach so all nodes represented by circles are normal nodes and all nodes represented by plus (+) are advance nodes ,with star (*) are cluster heads. For more clear specification we have used lines to represent the area of given cluster. Once the implementation starts, the first view that comes to be seen is shown in figure above. The screen is divided in to various regions that are called clusters. Each cluster thus formed has a cluster head. The entire network has a base station that is responsible for the collection of data from all other nodes.

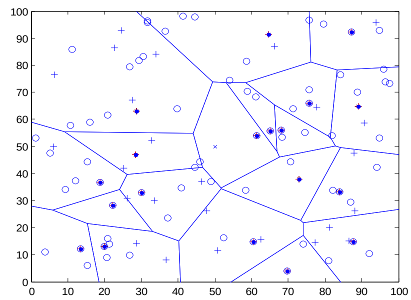

Fig 3 Initial configuration in Proposed LEACH *Dead nodes*

Figure 4 is demonstrating the LEACH with active as well as with some dead nodes represented by red diamond.

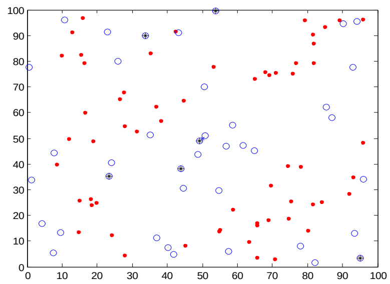

Fig 4 Network in active stage with some dead nodes LEACH Protocol

Figure 5 is represents the Proposed LEACH with active as well as with some dead nodes. It shows the dimension area of 100*100, the red diamonds represent the node dead so far during the life cycle of wireless sensor network. The only differences here are the blue lines which are representing the different clusters and each has its CH

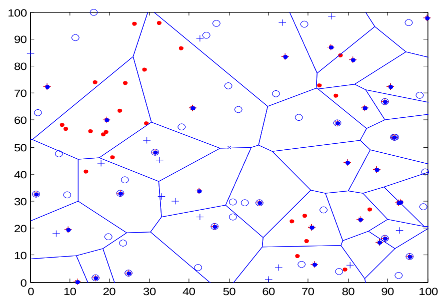

Fig 5 Dead nodes in Proposed LEACH

B. Packets sent to Base Station

Figure 6 shows the Packets that are sent to Base Station in Leach Protocol during the lifetime of the Leach protocol. It shows the throughput from 0 rounds to 1457

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as 1457 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network.

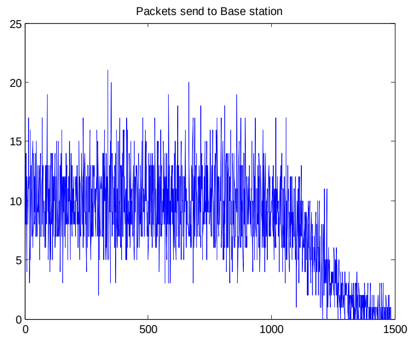

Fig 6 is Packets that are sent to Base Station in LEACH Protocol.

Figure 7 is showing the Packets that are sent to Base Station in Energy Leach Protocol during the lifetime of the Energy Leach protocol. It illustrates the throughput from 0 rounds to 2450 as 2450 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network. However it also shows the progress in terms of network life time and stability period than the simple LEACH protocol.

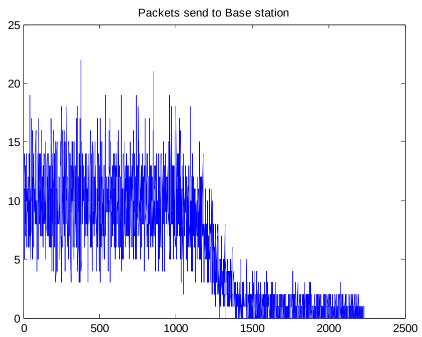

Fig 7 Packets that are sent to Base Station in Energy LEACH Protocol

Figure 8 shows the Packets that are sent to Base Station in Proposed LEACH Protocol during the lifetime of the Proposed LEACH protocol. In proposed leach last node dead at 6789 and first node dead at 1401 And it is clearly shown that they are quite more than figure 5 and 6 which is proving that proposed protocol is better with respect to packets send to base station.

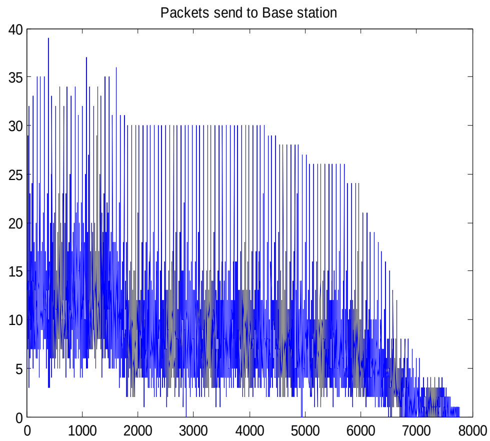

Fig 8 Packets that are sent to Base Station in Proposed LEACH Protocol

C. Packets sent to Cluster Head

Figure 9 is demonstrating the Packets that are sent to Cluster head in Leach Protocol during the lifetime of the Leach protocol.. It shows the throughput from 0 rounds to 1457 as 1457 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network.

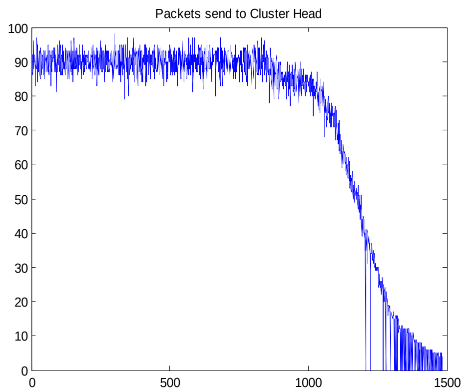

Fig 9 Packets that are sent to Cluster head in LEACH Protocol.

Figure 10 illustrates the throughput from 0 rounds to 2450 as 2450 is the overall lifetime of leach in our experiment. Here y axis shows the amount of packets sent during running time. It is clearly shown that the packets goes down rapidly recently after the first node dead, which clearly shows the benefits of the stability period of wireless sensor network. However it also shows the progress in terms of network life time and stability period than the simple leach protocol.

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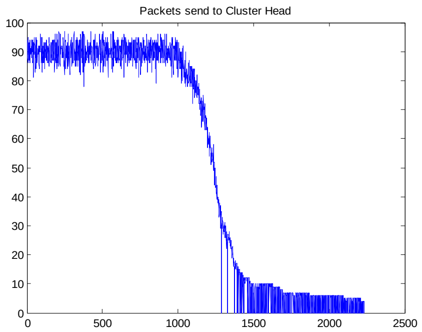

Fig 10 Packets that are sent to Cluster head in Energy LEACH Protocol.

Figure 11 is showing the Packets that are sent to Cluster head in Proposed Leach Protocol during the lifetime of the Proposed Leach protocol. And it is clearly shown that they are quite more than figure 10 and 9 which is proving that proposed protocol is better with respect to packets send to cluster head.

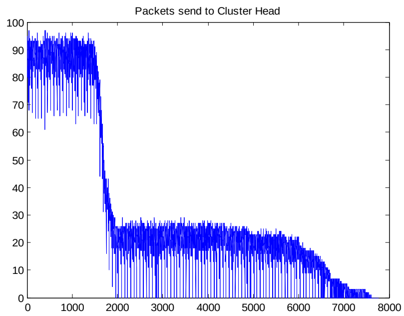

Fig 11 Packets that are sent to Cluster head in Proposed Leach Protocol.

D. Comparison

The below graphs shows the comparison between Leach, Energy Leach and Proposed Leach Protocol Comparison is made on the basis of dead nodes, dead normal nodes, dead advance nodes, alive nodes, alive normal nodes, and alive advance nodes in case of LEACH ,Energy LEACH and Proposed LEACH Protocol.

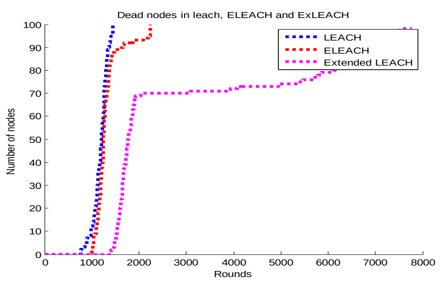

Fig 12 Shows the dead nodes in Leach, Energy Leach and Proposed LEACH Protocol

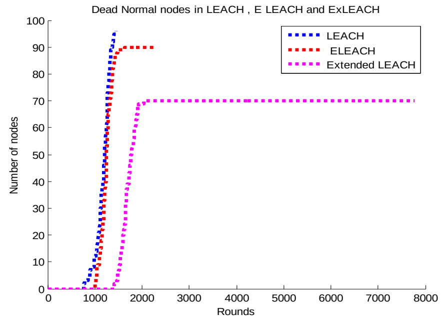

Fig 13 Shows the dead normal nodes in Leach, Energy Leach and Proposed Leach Protocol

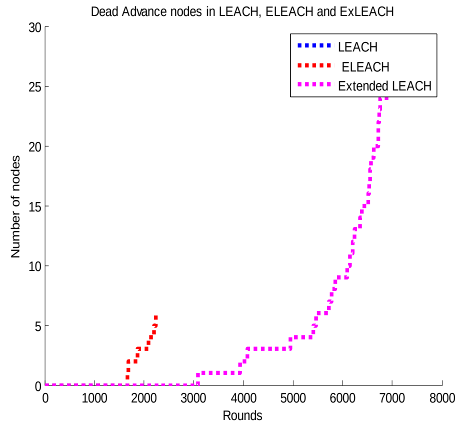

Fig 14 Shows the dead advance nodes in LEACH, Energy LEACH and Proposed LEACH Protocol

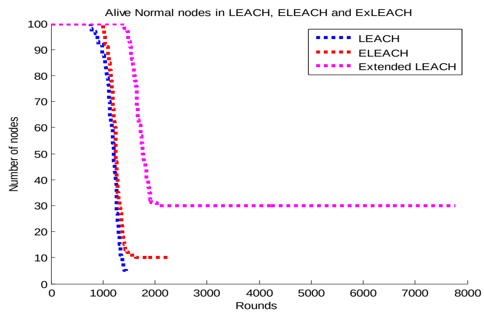

Fig 15 Shows the alive normal nodes in Leach, Energy Leach and Proposed LEACH Protocol

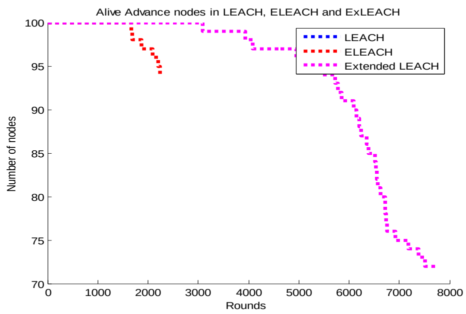

Fig 16 Shows the alive advance nodes in Leach, Energy Leach and Proposed LEACH Protocol

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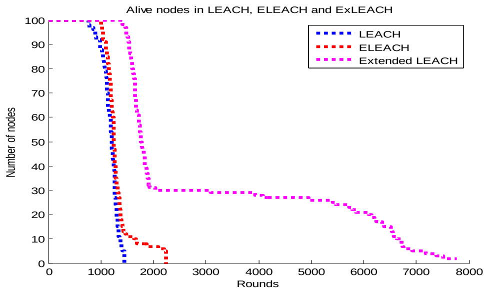

Fig 17 Shows the alive nodes in Leach, Energy Leach and Proposed Leach Protocol

VII. CONCLUSION & FUTURE WORK

We considered a protocol for WSN called LEACH protocol which is the most essential protocol in wireless sensor network which utilizes cluster based upon broadcasting technique. Followed by an overview of LEACH and Energy LEACH protocol implementations, then we proposed a new version of LEACH protocol called Enhanced LEACH protocol (Proposed LEACH).The concluded research work implemented a new improved clustered heterogeneous network where advanced nodes elect themselves as cluster heads, for the increasing number of rounds based on their higher initial energy relative to other nodes. In Enhanced LEACH, the cluster members are informed about the status of their CH. This provision is missing in LEACH and Energy LEACH protocol. Enhanced LEACH is more effective. It also improves the stable region of the clustering based hierarchy process using the parameters of heterogeneity like the fraction of advanced nodes (m) and secondly the additional energy factor between the advanced nodes and normal nodes (α). Comparison of proposed algorithm is also drawn with existing methods to evaluate the performance of proposed algorithm. It is found that proposed algorithm provides better results than existing, as we have extended the stability time or when the first node dead time. Also last node dead or network lifetime is also increased. The work done on the implementation of the protocol as part of this thesis has future implications where in near future the proposed algorithm will be implemented in real time systems by using the embedded systems. The results can be further generalized if database includes higher number of nodes as division; nodes will come up with some potential overheads so in near future we will try to reduce these overheads. Moreover future works may concentrate on achieving better energy efficiency in routing mechanism for wireless sensor nodes.

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