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Performance Analysis and Comparison of Cluster Based Routing Protocol in in WSN

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ABSTRACT

A wireless sensor network is the network having less cost, less power, compact size and multi functional sensor nodes. In Wireless Sensor Network, these nodes have a confined transmission range, and their processing and storage capabilities and their energy resources are also limited. However, in wireless sensor networks there is a requirement of more effective methods for data processing and forwarding. Routing protocols in WSNs emphasize on data dissemination, limited battery power and bandwidth constraints in order to accelerate adequate working of the network, thereby increasing the lifetime of the network. In this paper, we have compared and studied two main hierarchical based routing protocols and also optimized values for different parameters under certain assumptions in order to increase the network life time. The results shows that SEP protocol performs better than LEACH protocol.

Keywords :— Wireless Sensor Networks, Routing Protocol, Hierarchical Protocols, Energy efficiency

I. INTRODUCTION

A WSN is a network consisting hundreds or thousands of sensor nodes. These nodes are battery operated ,self originating and random in nature. These sensor nodes are large in number, low-power ,low-cost and multipurpose wireless sensor nodes, which facilitates sensing, communicating and computing capabilities [1,2] .Sensor nodes can communicate between each other and also can communicate directly to external base-station (BS). These sensor nodes monitor the atmospheric condition in the surrounding environment that can be done to get the features of the event happening at the place where the sensor nodes are deployed. A multiple number of these sensor nodes are either deployed in predetermined places or irregularly deployed over a terrain area and are connected through wireless links to form a WSN. These sensor nodes communicate over limited distance through a wireless medium and cooperate to achieve a common task, for instance, environment monitoring and industrial process control etc.[3]. The applications of WSNs in the military field consists of surveillance, intrusion detection ,etc. However, WSN are now also used in many civilized application too, including environment and location monitoring, medical applications, traffic control etc.

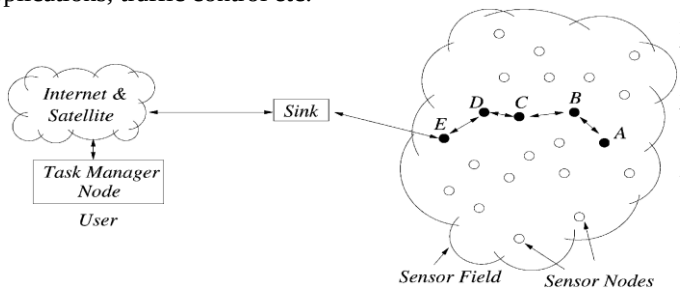

Fig. 1(a): Sensor nodes scattered in a sensor field [6]

Each node consists of three basic components as shown in Fig.1(b).

- Sensing unit
- Processing unit
- Transmission unit

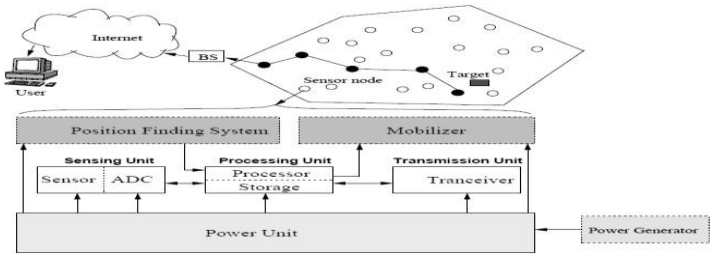

Fig.1(b):structural view of sensor network [2]

The main job of node is to sense the data from the environment, process it and send the data to the sink. These sensor nodes can either make a path to send the data to the sink or to other nodes in a way that the data ultimately reaches the sinks. In multiple applications, sensor nodes suffer from confined energy supply and communication channel bandwidth. These nodes are battery operated and hence network lifetime depends on the power consumption of battery [4]. In multiple situations it is very hard and even impossible to change or reload batteries for the sensor nodes. WSNs are distinguished with higher levels of node deployment, higher unstability of nodes, and a lot of power usage, and memory limitation. Therefore, the unique features and limitations bring on many new challenges for the enhancement and application of WSN [5]. Due to the confined energy of multiple number of densely deployed sensor nodes, it needs a suite of network protocols to control various

network and handle functions like synchronization, node localization, and network security. The conventional routing protocols have many drawbacks when applied to WSNs, which are mainly because of the energy-constrained characteristic of those networks [3].To accomplish these and other sensor networks applications, we need wireless ad hoc networking techniques. However, multiple protocols and algorithms have been implemented for conventional wireless ad hoc networks, they are not perfect for the unique features and application requirements of sensor networks. To justify this point, the contrast between sensor networks and ad hoc networks are mentioned below:

•The number of sensor nodes in a sensor network can be many more times greater than the nodes in an ad hoc network.

•The density of Sensor nodes deployment is more.

•Sensor nodes are liable to failures.

•The topology of a sensor network does not remain constant.

•Sensor nodes are based on broadcasting the data whereas most ad hoc networks are based on point-to-point communications.

• Sensor nodes are constrained in power, memory and computational capacities, etc.

•As sensor nodes have large amount of overhead and sensors ,they may not have global identification (ID).

A large number of experiments have been done to explore and overcome the limitations of WSNs and solve design and application problems.

In this paper two routing protocols for sensor network like Stable Election Protocol(SEP) and Low Energy Adaptive Clustering Hierarchy (LEACH) are discussed and compared ,keeping main attention on cluster based routing protocols. LEACH is important because it is self organizing ,adaptive clustering protocol that uses randomization to distribute energy load evenly. Cluster member elects cluster head to avoid excessive energy consumption. Section 1 gives the introduction of the wireless sensor network .Section 2 describes the network protocol stack. In Sections 3, the network design challenges and routing issues are described. In Section 4, various routing protocols are classified. Section 5, gives the detailed comparison of protocols. Section 6 describes motivation and detailed study of LEACH and SEP. Section 7, describes performance matrices. Section 8 describes the simulation environment and section 9 includes simulation results. Finally, conclusion and future work.

II. SENSOR NETWORK COMMUNICATION ARCHITECHTURE

The sensor nodes are usually distributed in a sensor field . These dispersed sensor nodes has the abilities to aggregate data and send data back to the sink and the end users [6]. Data is sent back to the end user using multihop infrastructure less network via sink as shown in Fig. 1(b). The communication between sink and task manager may take place via internet or satellite. The protocol stack used by the base station and all nodes is given in Fig. 3. This protocol stack consolidates routing and power consciousness, combines data with networking protocols, communicates using limited power via wireless medium, and advances cooperative efforts of sensor nodes. It comprises of the application layer, network layer, transport layer, data link layer, physical layer, power management plane, task management plane and mobility management plane. Preservation of the flow of data is done by the transport layer, if the sensor networks application requires it. After the network layer receives the data from the transport layer, it manages the routing of data. Since the environment is sonorous and sensor nodes can be movable, the Medium Access Control protocol must be power aware and should minimize collision with neighbor's broadcast. The requirement of a simple but tough modulation, transmission and receiving techniques is addressed by physical layer. Moreover, the power, task and mobility management planes controls the power ,task and movement distribution among the sensor nodes. Sensor nodes uses these planes to coordinate the sensing task and reduces the overall power usage[6]. The usage of power by the sensor nodes is monitored and managed by power management plane . The mobility management plane finds and maintains the movement of sensor nodes, so a way back to the user is always maintained, and the sensor nodes can keep track of who are their neighbor sensor nodes. The task management plane controls and maintains the sensing tasks given to a particular area .These management planes are required, so that sensor nodes can do the task together in a power efficient way, send data in a mobile sensor network, and exchange resources between sensor nodes. Without these management planes each sensor node will work on individual basis. From the whole sensor network view, it is more conventional if sensor nodes can associate with each other, so the lifetime of the sensor networks can be extended.

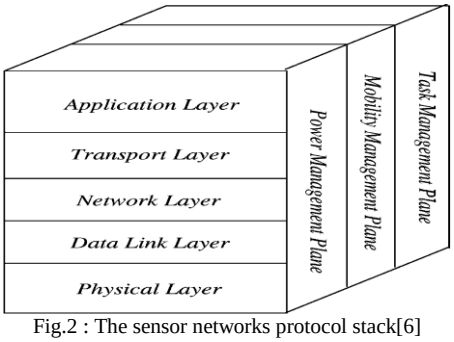

Fig.2 : The sensor networks protocol stack[6]

The proposed scheme works on network layer.

Network layer

In Network layer, there is distributed and dense deployment of sensor nodes in the field, either close to or inside the phenomenon. These nodes are battery operated which effects the life time of wireless sensor network. Because if a single node in the sensor network goes down i.e. dies ,then the entire network gets collapsed which in turn results in worst communication required for different applications like

monitoring, object tracking etc. where the route and route back information of every data is required. Hence routing protocol is very essential in WSN communication. Special multihop routing protocols between the sensor nodes and the base station are needed. The ad hoc routing techniques already proposed in the survey do not usually fit the requirements of the sensor networks. The networking layer of sensor networks is usually designed according to the following principles:

- Power efficiency is usually a crucial consideration.
- Sensor networks are normally data centric.
- Data consolidation is needed only when it does not inhibit the collaborative effort of the sensor nodes.
- An ideal sensor network has attribute-based addressing and position awareness.

Open research issues:

These protocols need to be improved or many new protocols need to be implemented to mark higher topology changes and higher scalability. Also, new internetworking proposals should be implemented to allow easy communication between the sensor networks and external networks e.g. Internet

III. NETWORK DESIGN CHALLENGES AND ROUTING PROTOCOL

The designing of routing protocols for WSNs is demanding because of multiple network issues. WSNs tolerates the problems of any network resources, for instance, energy, bandwidth, processing unit, and storage etc.[8],[9]. The design challenges in sensor networks highly includes the following main aspects [3],[8],[9]:

Constrained energy : Sensor nodes are mainly dependent on the battery for power. Since batteries can't be changed ,more care should be taken while using the available energy.

Locations of sensors: This is another important demand that is faced in the designing of routing protocols is to handle and control the positions of the sensors. Many other proposed protocols considers that the sensors are either endowed with global positioning system (GPS) receivers or with other localization technique to know about their positions [10].

Limited hardware resources: Besides confined energy capacity, sensor nodes also suffer the problems with processing and storage capacities, and this is the reason that they perform limited computational functionalities. This results into hardware constraints causing confront in developing software and designing network protocol for sensor networks.

Enormous and indiscriminate node deployment: The deployment Sensor node in WSNs is application reliant and can be either manual or random which ultimately influences the performance of the routing protocol. If the nodes are dispersed randomly in certain applications ,then resultant distribution of nodes will result in non uniform, so optimal clustering becomes necessary to allow network connectivity energy efficiency.

Data collection: As sensor nodes can create significant amount of unwanted data, analogous packets from different nodes can be gathered so that the number of transmissions is lowered. Data aggregation technique is used to attain energy efficiency and data transfer optimization in routing protocols.

Scalability: The changes adapted by the sensor network should be in increasing size. Because some nodes may go to another position and some nodes may join newly to the network.

IV. CLASSIFICATION OF ROUTING PROTOCOLS

The main objective of Routing protocols in WSNs is to use the scarce resources of sensor nodes effectively in order to increase the lifetime of the network. Numerous techniques of routing can be practiced for various applications depending on their requirements. Applications can be time critical or requiring frequent updates, they may need perfect data or long lasting, less definite network, they may require frequent data or event driven output. Routing methods can even be developed and used for specific application. Routing in wireless sensor networks distinguishes from conventional routing in fixed networks in various ways. They are infrastructure less, wireless links are unreliable, sensor nodes are liable to failures, and routing protocols have to meet energy saving requirements [11]. Many routing algorithms were implemented for wireless networks in general. Most conventional routing protocols proposed for WSNs are as follows:

1. Data Centric routing
2. Hierarchical routing
3. Location based routing

1.Data Centric routing:

In flat based network every node plays the same role & collaborates together to perform sensing task. Due to the presence of large number of nodes, it is not feasible to assign global identifier for every node, data centric routing is used where the queries are performed to the sender and data is transmitted to the receiver node. BS sends the queries to the selected zones and waits for the data response from the selected zones of sensor nodes.

2. Location based routing:

Location based routing protocols are using location information to get route back information.. In this the nodes are equipped with Global Positioning Systems and scattered in a selected network. The position of nodes can be found with the help of GPS. On the basis of incoming signal strengths, the distance between the neighboring nodes can be determined. When the distance between any two nodes in the network is obtained with the help of signal strength, it is easy to know

about the co-ordinates with the exchange of information or data with the neighboring nodes.

3. Hierarchical routing:

Hierarchical routing is also called as cluster based routing. The main objective of establishing the cluster based routing protocol is to minimize the network traffic towards the sink [19]. The main moto of hierarchical routing is reduction of energy consumption of sensor nodes, in which advance nodes can be used to process and send the signal while the normal nodes can be used to perform sensing task. Only low energy nodes are considered for making network path. Hierarchical routing is two layered routing where the one layer is used for identifying the cluster heads and other is used for routing [20, 21]

Routing protocols for WSNs		
Data centric protocol	*Hierarchical protocol*	*Location based protocol*
1.flooding & gossiping	1.LEACH	1.MECN
2.SPIN	2.PEGASIS	
3.directed diffusion	3.TEEN	2.SMECN
4.rumour routing	4.APTEEN	
5.ACQUIRE	5.SEP	3.GEAR

Fig. 4 : classification of routing protocols[12]

V. COMPARISON OF CLUSTER BASED ROUTING PROTCOLS

The Table 1 shows the comparison between some clusters based routing protocol on the issues of energy efficiency, load balancing etc. These cluster based routing protocol includes LEACH,PEGASIS,TEEN,APTEEN and SEP. These protocols are based on clustering, power efficiency, threshold sensitivity , and heterogeneous environment concepts. In these protocols ,there are two types of protocols homogeneous and heterogeneous. Every protocol has some or the other advantages and disadvantages. The summarized information of each protocol is mentioned in the below table:

Sr. No.	Reference	Protocol	Merits	Demerits
1.	W.Heinzelman, A. Chandrakasan H. Balakrishnan ,Energy-efficient communication protocol for wireless sensor networks, in: Proceeding of the Hawaii International Conference System Sciences, Hawaii, January 2000[5]	Low-energy adaptive clustering hierarchy (LEACH)	1. It is one of the most frequent used hierarchical routing algorithms in sensor networks. 2. LEACH protocol divides the total wireless sensor network into many clusters. Any node that is served as a CH in present round cannot be selected as the CH again; therefore each node can share the load equally which is imposed on Cluster heads.	1. The cluster heads are elected randomly, so the optimal number and distribution of cluster heads cannot be ensured. 2. The communication between cluster heads and BS is 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.

2.	S. Lindsey and C. S.Raghavendra, (March 2002), "PEGASIS: Power Efficient Gathering in Sensor Information Systems," Proceedings of the IEEE Aerospace Conference, Big Sky, Montana[15]	Power Efficient Gathering In Sensor Information System (PEGASIS)	1. It is an improved version of LEACH. 2. This protocol can beat LEACH for different network sizes and topology cluster formation in LEACH, and minimizes the number or quantity of signal transmission volume through the chain of information aggregation. 3. The energy load is distributed uniformly within the network. To prevent the subsequent early death of sensor node, all sensor nodes act as leader successively.	1. In PEGASIS sensor nodes usually or probably die early. 2. The communication manner suffers from excessive delays caused by the one or single chain for distant nodes and a high probability for any node to become a bottleneck.
3.	A. Manjeshwar, D.P. Agrawal, TEEN: a protocol for enhanced efficiency in wireless sensor networks, in: Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001[16]	Threshold sensitive Energy Efficient sensor Network protocol (TEEN)	1. Supported by the thresholds, data transmission are often controlled commendably, so that it reduces the energy transmission consumption and improves the effectiveness and utility of the receiving data. 2. TEEN is competent for reacting to major changes in the sensed attributes that is appropriate for reactive scenes and time decisive applications	1. It is not appropriate for periodic reports applications since the user might not get any data at all if the values of the attributes may not arrive at the threshold. 2. If CHs don't seem to be within the communication range of each other, the data may be vanished, because information transmission is accomplished only at CHs.
4.	Vadlamudi, Ravindranath, and Syed Umar. "A Review of APTEEN in Wireless Sensor Networks." *International Journal of Science, Engineering and Computer Technology* 3.9 (2013): 306[29].	The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN)	1. APTEEN combine-s both proactive policies, as that of LEACH, and reactive policies, as that of TEEN. 2. It is flexible enough and set the count-time interval and the threshold values for the energy consumption by changing the count as well as the threshold values.	1. There exist supplementary complexity which is required to implement threshold functions and the count time. 2. Actually, each TEEN and APTEEN has the identical drawbacks of additional overhead and complexity of cluster construction in multiple levels.
5.	S. George, I. Matta, A. Bestavros. 2004 "SEP: A Stable Election Protocol for clustered heterogeneous Wireless Sensor Networks". In Proceedings of Second International Workshop on Sensor and Actuator Network Protocol and Applications (SANPA), Boston, MA, August[14]	Stable election protocol(SEP)	1.At each election round,there is no requirement of universal knowledge of energy.	1.The election of cluster head is not dynamic between advanced node and normal node.

Table No. 1

VI. MOTIVATION

The proposed scheme works on two routing protocols, Low Energy Adaptive Clustering Hierarchy and Stable Election Protocol:

1. LEACH
2. SEP

There are many applications where the spatial density of sensors is a problem. Considering those constraints with the ongoing current technology ,the cost of a sensor is much more greater than the cost of embedded batteries. As we are going to work on certain applications which needs only hierarchical protocols, we are restricting only to the cluster based protocols. As tested earlier, the results shows that ,the hierarchical routing protocols performs better for enhancing the network life time, reducing power consumption etc as compared to data centric and location based protocols. Here the scheme compares homogeneous and heterogeneous environment based protocols. Now among these number of hierarchical

protocols, literature survey says that, LEACH is the one which is used frequently along with the good results in homogeneous environment. And SEP an improvement over LEACH protocol, performs better in heterogeneous environment.

A. LEACH (low energy adaptive clustering hierarchy)

LEACH is the crucial and most well known energy efficient hierarchical clustering protocol for WSNs that was implemented for lowering power dissipation. In LEACH, the clustering task is wheeled within the nodes, depending on time period. Every cluster head (CH) forwards the data to the sink using Direct communication. Clustering is used to increase and enhance the life of the sensor network. LEACH is dependent on an data aggregation technique that combines the actual data into a smaller size of data that does not carries any redundant information to any single sensor. In LEACH, the entire network is differentiated into multiple cluster of sensors, which are created by using localized coordination and control, which not only lowers the amount of data that are sent to the sink, but also to make routing and data distribution more scalable and tough. LEACH uses rotation technique of high-energy CH location rather than choosing in statically, to give chances to all sensors to act as CHs and avoid the battery consumption of a single sensor node and expiring quickly. The operation of LEACH is differentiated into different rounds consisting of two phases each namely (i) a setup phase to arrange the network into clusters, Cluster Head advertisement, and transmission schedule generation and (ii) a steady-state phase which is for data collection, compression, and transmission to the sink.

Operation:

LEACH operations can be divided into two phases:-

1. Setup phase
2. Steady phase

In the setup phase, the clusters are formatted and a cluster-head (CH) is selected for each cluster. While in the steady phase, sensation of data takes place and sent to the central base station.

The steady phase takes more time as compared to the setup phase, to minimize the overhead cost.

1. Setup phase :- During the setup phase, a predetermined fraction of nodes, p, selects themselves as cluster-heads. Selection criteria is according to a threshold value, T(n). The threshold value relays upon the percentage to become a cluster-head- p, the current round r, and the set of nodes that have not become the cluster-head in the last 1/p rounds, which is denoted by G. The formulae is as follows :

$$T(n) = \frac{P}{1 - P * (r \bmod P^{-1})} \qquad \forall_n \in G \qquad (1)$$

$$T(n) = 0$$

Every node who wants to be the cluster-head selects a value, between 0 and 1. If this random number does not exceeds threshold value, T(n), then the node becomes the cluster head for the current round. Broadcasting of an advertisement message to the rest of the nodes in the network is elected by each CH to invite them to join their clusters. Based upon the energy of the advertisement signal, the non-cluster head nodes decide to join the clusters. The non-cluster head nodes then informs their respective cluster-heads that they will be under their cluster by transmitting an acknowledgement message. Once the acknowledgement message is received, depending upon the number of nodes under their cluster and the type of information required by the system , the cluster-heads makes a TDMA schedule and assigns each node a time slot in which it can send the sensed data. The broadcasting of TDMA schedule is done to every cluster to every member of cluster. If the size of any cluster becomes much larger, the cluster-head may select another cluster head for its cluster. The cluster-head selected for the current round cant again become the cluster-head until all the other nodes in the network have not become the cluster head.

2.Steady phase :-During the steady phase, the sensor nodes i.e. the node which is not a cluster head starts sensing data and sends it to their cluster-head according to the TDMA schedule .After receiving data from all the member nodes, the cluster head node collects it and then sends it to the sink .After a certain duration which is determined a priori, the network again goes back into the setup phase and new cluster-heads are selected. Each cluster communicates using different CDMA codes in order to reduce interference from nodes relating to other clusters. Figure 6.1 shows the flowchart of LEACH protocol.

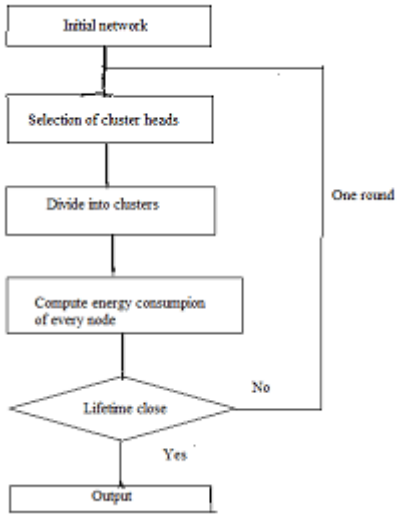

Fig. 6.1: Flow chart of LEACH protocol[13]

During setup phase each node will calculate their probability of becoming the cluster head [13].

As given in [13], probability is given by-

$$T(n) = \frac{p}{1-p*(r \bmod p^{-1})} \qquad \forall_n \in G \qquad (2)$$

$$= 0 \qquad \forall_n \notin G$$

Where n is a random number between 0 and 1. P is the cluster Head probability and G is the set of nodes that were not the cluster Heads in the previous rounds.

B. SEP(Stable Election Protocol)

A Stable Election Protocol (SEP) is extended version of LEACH protocol, which aims towards the use of heterogeneous sensor in wireless sensor networks. The operation of SEP is similar to that of LEACH except one thing ,i.e., the sensor used in SEP are of different energy level SEP is based on weighted election probabilities of each node to become cluster head in perspective of their respective energy. This scheme guarantees the cluster head election is randomly selected and distributed based on the fraction of energy of each node confirming a uniform use of the nodes energy. In SEP, two types of nodes (normal and advanced) are considered. This enhances the stability period i.e. the time period before the first dead node. A Stable Election Protocol for clustered heterogeneous wireless sensor networks is created to enhance the time period before the first node dies. In SEP two levels of nodes are included: the advanced and normal nodes in accordance with their initial energy. According to the remaining energy and weighted election probabilities, each node can become CH.SEP does not depend on global knowledge of energy at every election round. SEP is scalable. Fig. 6.2 shows the flowchart of SEP protocol.

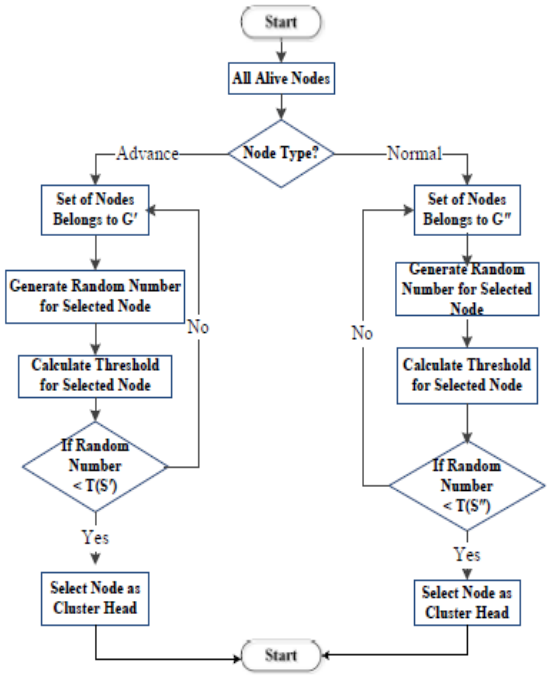

Fig. 6.2: Flow chart for SEP protocol[14]

As shown in [14],Weighted probability for normal and advance node is given by:

For normal node:

$$Pnrm = \frac{Popt}{1+\alpha.m} \qquad (3)$$

For advance node:

$$Padv = \frac{Popt\times(1+\alpha)}{1+\alpha.m} \qquad (4)$$

Where *pnrm* and *padv* are probability of normal node and advance node. α is the additional energy in perspective with normal energy. *m* is the probability of advanced nodes in normal nodes. *Popt* is the optimal probability[14].

VII. PERFORMANCE MATRICES USED IN SIMULATION

There are several performance matrices in the wireless sensor network area as mentioned below .In our simulation we are working on the stability period matrix of each protocol. The details of the below mentioned matrices are given in [18].

Stability Period: It is the time period between the starting of network process and death of very first node in the network.

Instability Period: It is the time period between the death of very first sensor node and very last sensor node of the network.
Network lifetime: It is the time period between the initialization of network process and the death of the very last alive sensor node in network.
Cluster heads per round: These are some percentage of nodes, that consolidates the sensed data of their associated cluster members and directly send to BS.
Alive nodes per round: These are total number of nodes that have not yet spent all of their energy.
Packets to BS: These are total data packets that are successfully sent from their CHs to the BS.

VIII. SIMULATION ENVIROMENT

Sensor networks are simulated using MATLAB R2009a simulator. To evaluate the performance of the clustering routing protocols in wireless sensor network the simulation parameters are shown in table 2.The nodes are randomly distributed in the area 100mX100m.The base station is located 50mX150m.The number of nodes deployed in the network is varied from 25 to 150 nodes. The initial energy used by the sensor nodes is varied from 0.1J to 0.5J and similarly with the percentage of advanced node is varied. The number of rounds used is 2000.

Parameters	Value
Network Size	100mX100m
Sink Location	(50,150)m
Number of nodes	25,50,75,100,125,150
Initial energy,E0	0.1,0.2,0.3,0.4,0.5J
Data packet length	4000bit
TX/RX power	50nj/bit
EDA	50nj/bit
Percentage of advanced nodes, m	0.1,0.2,0.3,0.4,0.5
Number of rounds	2000
A(additional energy for advanced node)	1

Table No:2

IX. SIMULATION RESULTS

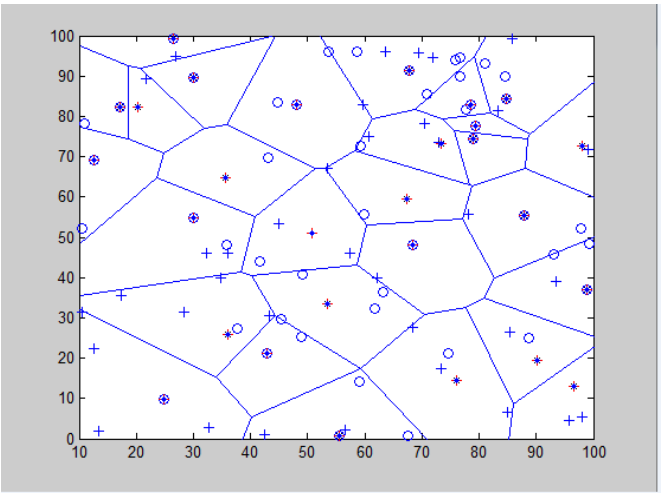

Fig .9: Field distribution-1

Fig. 9 shows the initial field distribution of the network, where LEACH protocol is implemented. A 100mX100m field is taken and nodes are randomly placed in it. The sink/base station, which is denoted by a X, is placed at the centre of the field (50, 150). Placing the base station at the centre is convenient so that no node finds it out of its transmission range. Here, the advanced nodes are shown by a plus symbol (+) and the normal nodes by a circle (o)

9.1. Effect of change in the values of election probability to become cluster head .

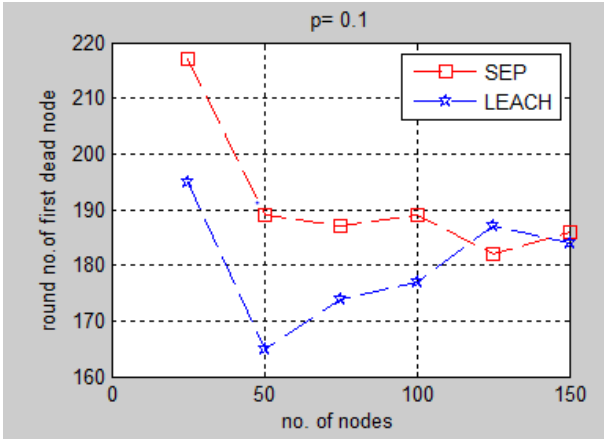

Fig. 9.1(a): Effect on LEACH and SEP protocol, when p is 0.1

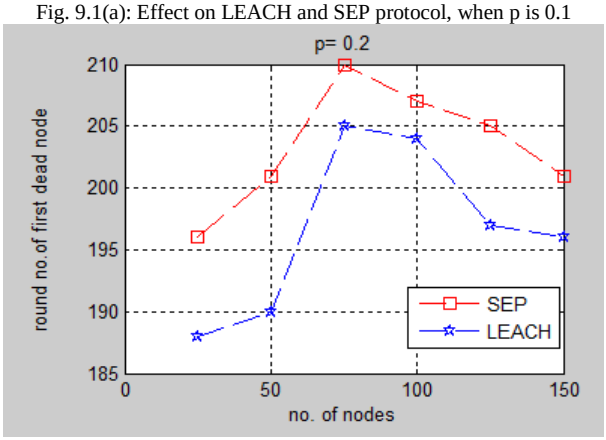

Fig.9.1(b): Effect on LEACH and SEP protocol, when p is 0.2

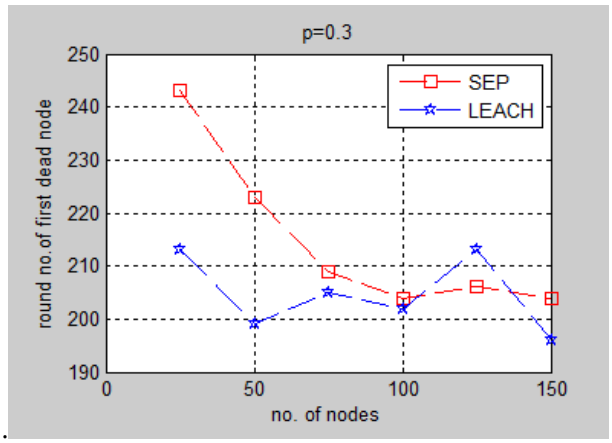

Fig. 9.1(c): Effect on LEACH and SEP protocol, when p is 0.3

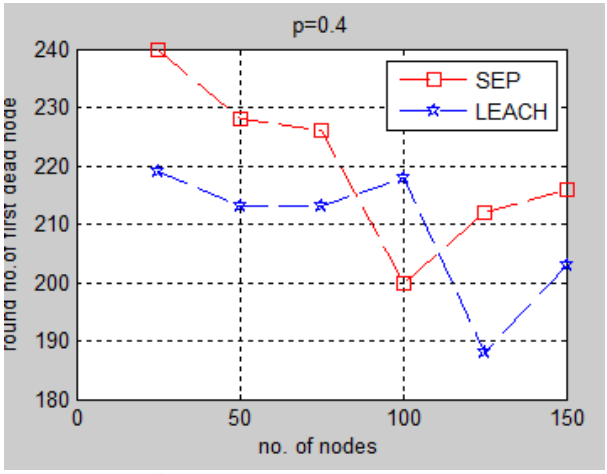

Fig.9.1(d): Effect on LEACH and SEP protocol, when p is 0.4

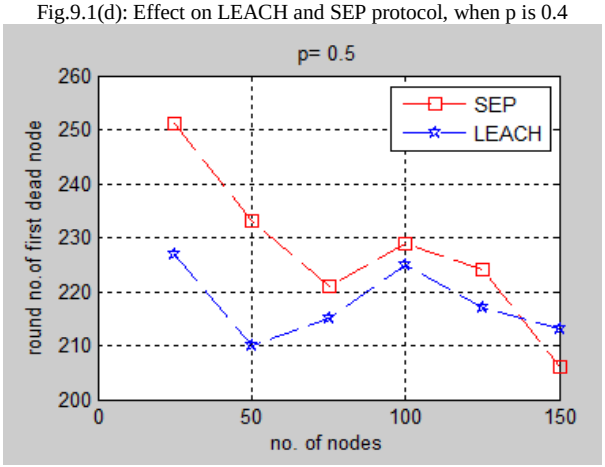

Fig. 9.1(e): Effect on LEACH and SEP protocol, when p is 0.5.

By analysing above graphs, when *P* i.e. election probability to become cluster head and number of nodes in the network is varied from 0.1 to 0.5 and 25 to 150 nodes respectively, it is observed that the round number at which the first node is dead in a network is greater in SEP as compared to LEACH in most of the cases. This is because of the heterogeneity i.e. advanced nodes containing more energy as compared to normal nodes present in the SEP protocol. Hence it is seen that more stability is achieved in SEP protocol. On an average the percentage gain obtained in SEP is approximately seen as 7.4%,3.2%,5.9%,7.6% & 5.4% respectively. In this case, the highest gain is obtained when the election probability to become cluster head in a network is 0.4 which is 7.6%.
However, it can also be seen that, there are some cases where even LEACH protocol is outperforming SEP protocol. This is because the election of the cluster head is not dynamic hence the nodes which are far away will be died first.

9.2. Effect of change in the percentage values of advanced node.

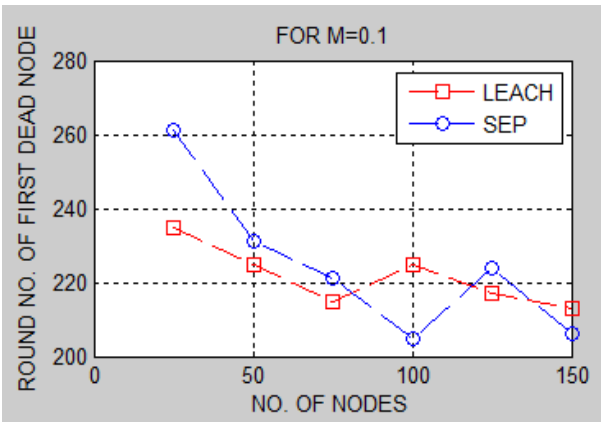

Fig. 9.2(a): Effect on LEACH and SEP protocol, when m is 0.1

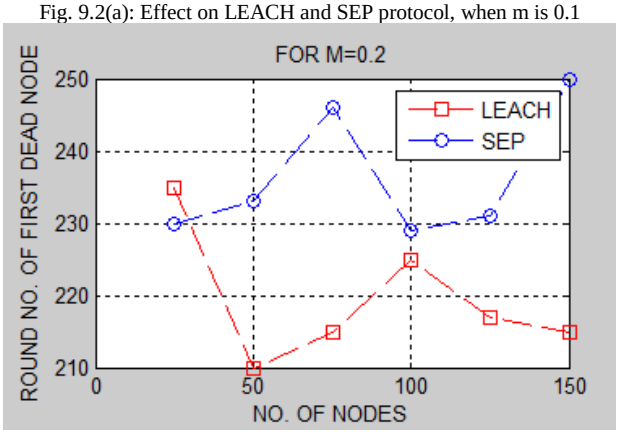

Fig. 9.2(b): Effect on LEACH and SEP protocol, when m is 0.2

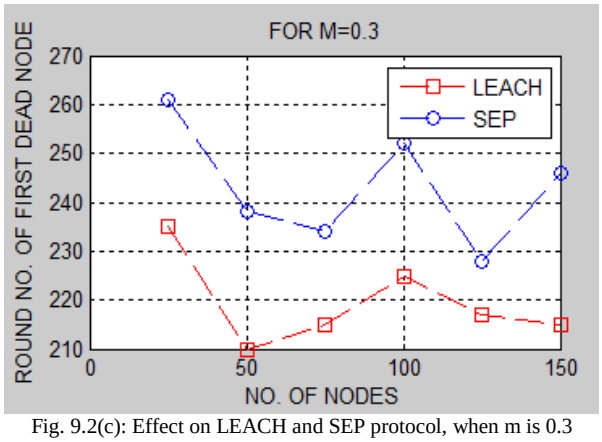

Fig. 9.2(c): Effect on LEACH and SEP protocol, when m is 0.3

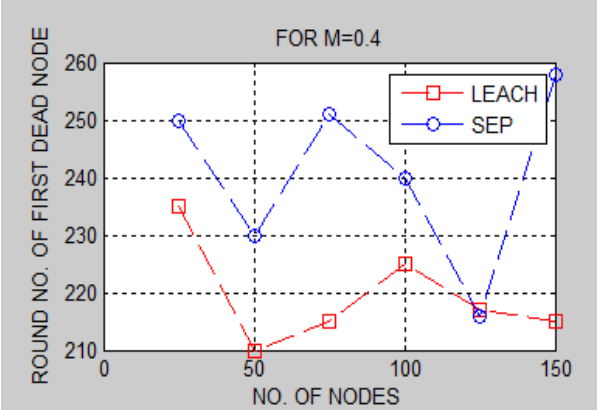

Fig.9.2(d): Effect on LEACH and SEP protocol, when m is 0.4

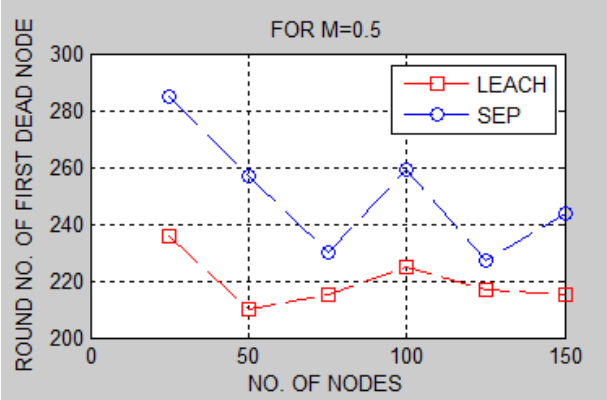

Fig. 9.2(e): Effect on LEACH and SEP protocol, when m is 0.5

By analysing above graphs, when *m* i.e. percentage of advanced node in a network and number of nodes in the network is varied from 10% to 50% and 25 to 150 nodes respectively, it is observed that the round number at which the first node is dead in a network is greater in SEP as compared to LEACH in most of the cases. This is because of the heterogeneity i.e. advanced nodes containing more energy as compared to normal nodes present in the SEP protocol. Hence when the percentage of advanced node is increased from 10% to 50% in the heterogeneous network of SEP, it is seen that more stability is achieved in SEP protocol. On an average the percentage gain obtained in SEP is approximately seen as 7.1%,13.2%,17.6%,14.4% & 17.5% respectively.

In this case, the highest gain is obtained when the total percentage of advanced node in a network is 30% which is 17.6%.

However, it can also be seen over here also that, there are some cases where even LEACH protocol is outperforming SEP protocol. This is because, as the election of the cluster head in SEP protocol is dynamic due to which the elected cluster head over here will not be an advanced node but a normal node.

9.3. Effect of change in initial energy of node

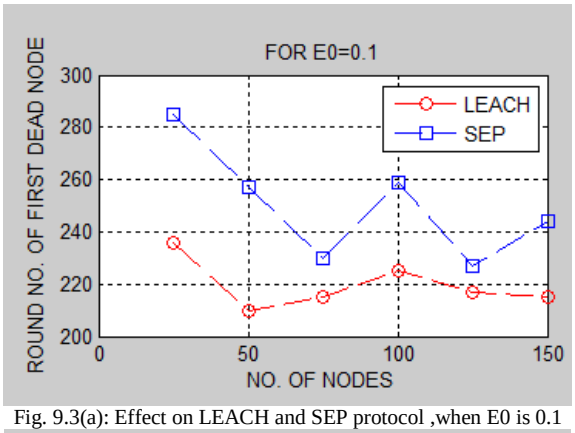

Fig. 9.3(a): Effect on LEACH and SEP protocol ,when E0 is 0.1

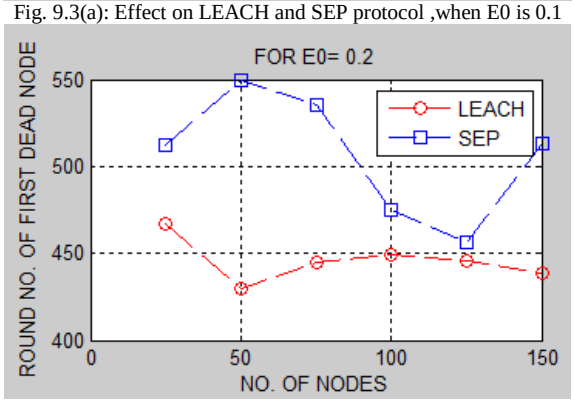

Fig.9.3(b): Effect on LEACH and SEP protocol, when E0 is 0.2

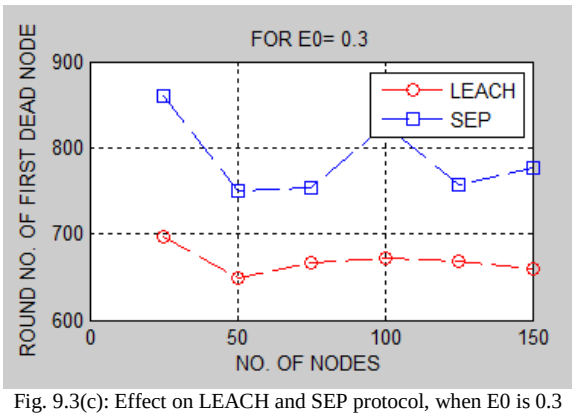

Fig. 9.3(c): Effect on LEACH and SEP protocol, when E0 is 0.3

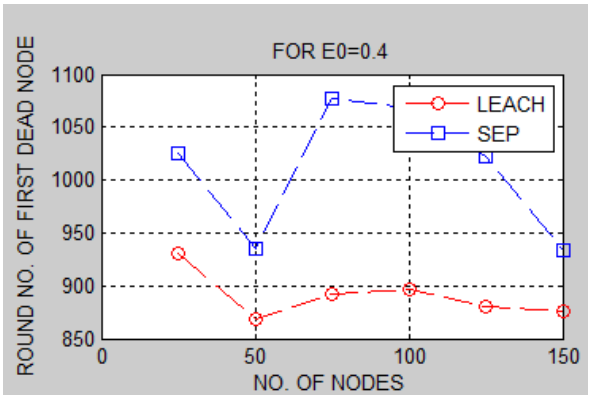

Fig.9.3(d): Effect on LEACH and SEP protocol, when E0 is 0.4

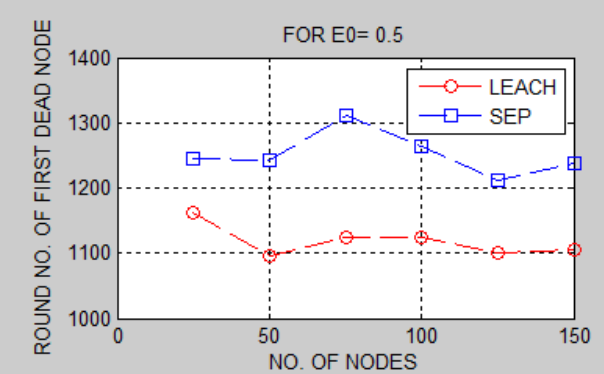

Fig. 9.3(e): Effect on LEACH and SEP protocol, when E0 is 0.5

By analysing above graphs, when *E0* i.e. initial energy of node in a network and number of nodes in the network is varied from 0.1J to 0.5J and 25 to 150 nodes respectively, it is observed that the round number at which the first node is dead in a network is greater in SEP as compared to LEACH in most of the cases. This is because of the heterogeneity i.e. advanced nodes containing more energy as compared to normal nodes present in the SEP protocol. Hence when the initial energy of every node is increased from 0.1J to 0.5J in the heterogeneous network of SEP ,it is seen that more stability is achieved in SEP protocol. On an average the percentage gain obtained in SEP is approximately seen as 8.5%,7.1%,10.4%,13.4% & 9.8% respectively.

In this case, the highest gain is obtained when the initial energy of node in a network is 0.4J which is 13.4%.

In every above cases, we find that all the graphs are in zig-zak pattern. This is because in some cases the flow of data traffic to the sink is more, hence the graph shows the increasing pattern, whereas, in some cases, we find that the graph pattern is decreasing as the flow of data traffic towards sink is less.

CONSOLIDATED RESULTS:

The bar graphs below shows the consolidated results of all the parameters on SEP and LEACH, and also concludes with all the perspective that SEP outperforms LEACH.

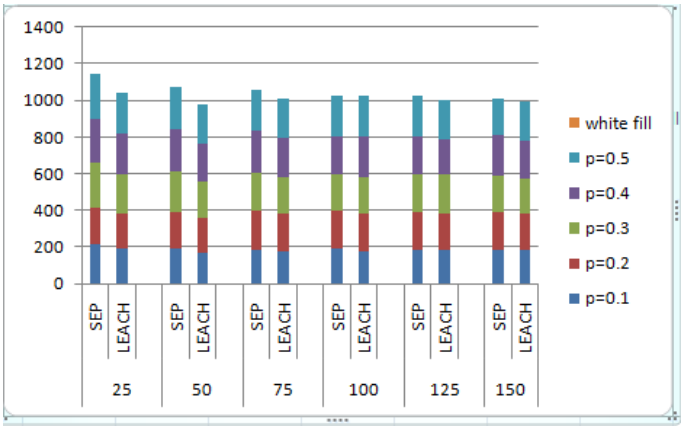

Fig.1- Consolidated result of effect of *P* on SEP and LEACH.

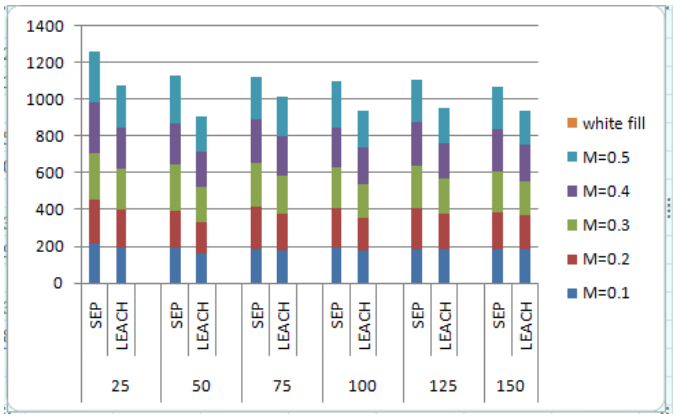

Fig. 2- Consolidated result of effect of *M* on SEP and LEACH

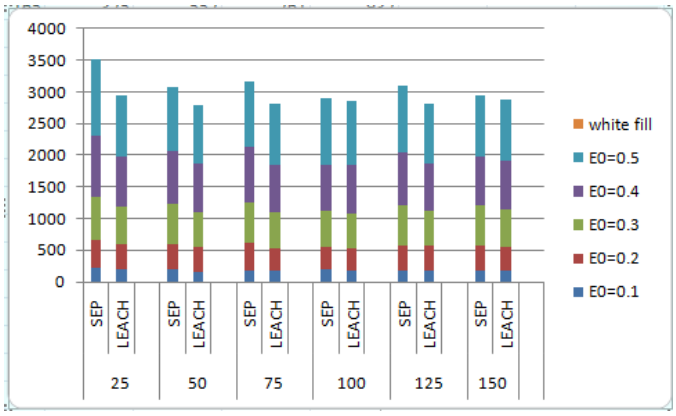

Fig.3- Consolidated result of effect of *E0* on SEP and LEACH

X. CONCLUSION

In this paper, cluster based energy efficient protocols LEACH and SEP are compared. The two routing protocols LEACH and SEP are analyzed using heterogeneous wireless sensor network. The simulation results show how the election criteria for cluster heads election , Initial Energy , and percentage of advance nodes affects the network stability. Results also shows that SEP performs better than LEACH

algorithm on network lifetime. We have evaluated the performance of LEACH and SEP using MATLAB. Future work will be to increase the network life time and scalability of LEACH protocol.

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