

## **Energy Efficient Hierarchical Clustering Algorithm for Heterogeneous Wireless Sensor Networks**

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**Abstract:** Wireless sensor networks are the collection of sensor nodes. These sensor nodes are small in size, powered with batteries and have limited storage and radio capability. In Wireless sensor networks that are hierarchically clustered with the heterogeneity of sensor nodes cluster head is responsible for the transmission of data from their cluster members to the base station. But SEP a heterogeneous aware protocol is based on weighted election probability of each node to become cluster head according to the remaining energy in each node. In these networks some of the sensor nodes become cluster head with more energy than the remaining cluster members. But there is no concept of energy consideration, both for normal nodes and advanced nodes as well for developing cluster heads. In the proposed routing technique, we have introduced the concept of Threshold energy for developing cluster head and other cluster members as well. Simulations are done in MATLAB and results are compared with SEP.

**Keywords:** WSN, SEP, Cluster head Cluster members, MATLAB, heterogeneous network, Base station (Sink).

### **1. INTRODUCTION:**

A Wireless Sensor Network (WSN) is a collection of wireless sensor nodes with limited energy and radio capabilities that could be mobile or stationary depend on the application and are located randomly on a dynamically changing environment. Selection of the routing strategies is an important issue for the efficient delivery of the packets from their source to destination. Also, in such networks, the applied routing strategy should ensure the minimum energy consumption and hence maximization of the lifetime of network [1].

The WSN is built of "nodes" – from a few to several hundreds or even thousands of nodes, where each node is connected to one or more sensors.

Sensor nodes consist of components which are capable of:

- 1) Sensing Data**
- 2) Processing Data and**
- 3) Also communicate between components to further transmit or receive the required data.**

The protocols and algorithms of such networks must possess self-organizing capabilities to ensure accurate and efficient working of the network.

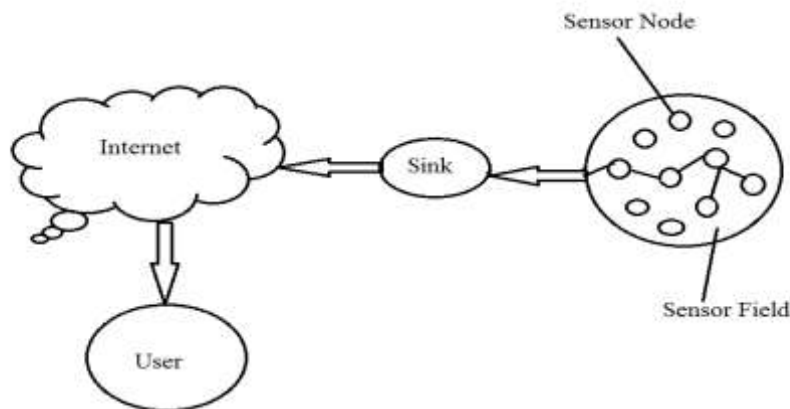
Due to advancement and technological evolution in Wireless Communications, the development in the field of WSNs is due to their low cost and variety of applications such as health, home and military etc. More research work is going on to solve different technical issues in various application areas.

### 1.1 Basic communication architecture in WSN:

A Wireless Sensor Network (WSN) consists of a number of sensor nodes and are scattered in an environment called sensor field. The basic communication architecture for WSN is shown by Fig.1.1

The sensing nodes present in sensor field communicate with sink via multiple hops. The sink communicates with user either with the help of internet or the satellite network [2].

The more complex network of the sensing nodes, the more expensive these nodes are and vice versa. Thus the cost and size are the main constraints of the wireless sensor networks.



**Fig 1.1 Basic Communication Architecture for WSN**

The size and cost of the sensor nodes will depend on the energy consumed in transmitting the data from source node to sink node or to the destination. Also memory resources, speed and the bandwidth are the factors which will affect the cost and size of the network of sensing nodes. Sensor nodes are based on the battery powered devices, so main focus here is to reduce the energy consumption of sensor nodes in the wireless network. Thus lifetime of the sensor nodes will be increased which will further enhance the stability of network nodes. Thus in WSN energy conservation is the main issue.

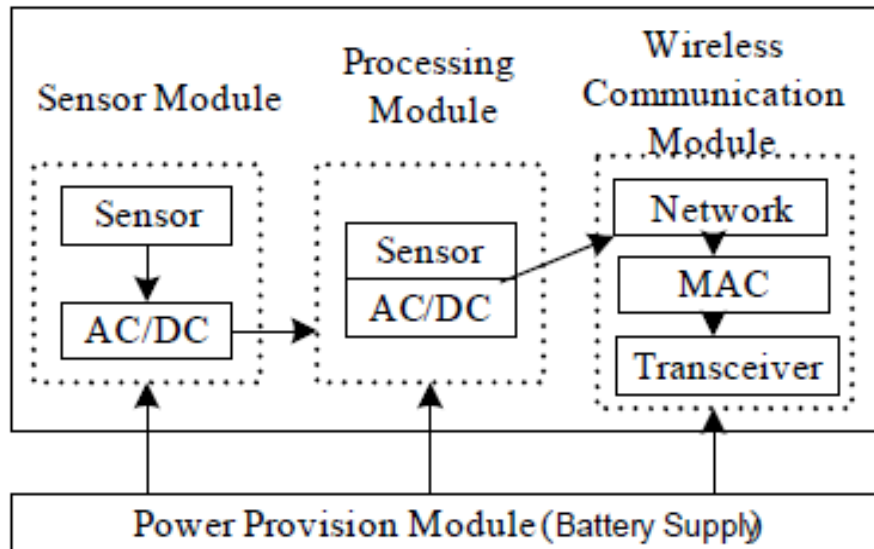
### 1.2 Architecture of WSN Sensor Node Network:

A sensor node in the sensor network is capable of performing some tasks like sensing some information, gathering sensed data and communicate with other sensor nodes or devices in the network used for performing that related task. Due to recent technological advances, the manufacturing of small and low cost sensors become technically and economically feasible and is easy to alter. Figure 1.2 shows the schematic diagram of sensor node components. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed for their working. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment.

The energy consumption of **sensor module** present in fig. 1.2 is due to a few numbers of operations. This includes signal sampling, ADC (Analogue to Digital signal conversion) and signal modulation. Also the energy consumption of this module is related to the sense operations of the nodes (periodic, sleep/wake, etc.).

For example in periodic mode the energy consumption is modelled as -

$$E_{\text{sensor}} = E_{\text{on-off}} + E_{\text{off-on}} + E_{\text{sensor-run}} \quad (1)$$



**Fig 1.2 Architecture of WSN Sensor Node Network.**

- $E_{\text{on-off}}$  - One time energy consumption of closing the sensor operation  
 $E_{\text{off-on}}$  - One time energy consumption of opening the sensor operation  
 $E_{\text{sensor-run}}$  - Energy consumption of sensing operation

The main activities of **Processing Module** are the sensor controlling, the protocol communication and the data processing. In most cases this module supports three operational states (sleep, idle, run).

$$E_{\text{cpu}} = E_{\text{cpu-state}} + E_{\text{cpu-change}} = \sum_{i=1}^m P_{\text{cpu-state}}(i) T_{\text{cpu-state}}(i) + \sum_{j=1}^n N_{\text{cpu-change}}(j) e_{\text{cpu-change}}(j) \quad (2)$$

- $E_{\text{cpu}}$  - Processor Energy Consumption  
 $E_{\text{cpu-state}}$  - Sum of the state energy consumption  
 $E_{\text{cpu-change}}$  - State-transition energy consumption  
 $P_{\text{cpu-state}}(i)$  - Power of state  $i$  that can be found from the reference manual

- $T_{cpu-state}(i)$  - Time interval in state  $i$  which is a statistical variable  
 $N_{cpu-change}(j)$  - Frequency of state transition  $j$   
 $e_{cpu-change}(j)$  - Consumption of one-time state transition  $j$

And in **Wireless Communication Module** The total power consumption for transmitting PT and for receiving PR, is denoted as

$$PT(d) = PTB + PTRF + PA(d) = PT0 + PA(d) \quad (3)$$

$$PR = PRB + PRRF + PL = PR0 \quad (4)$$

- PT - Power Consumption for Transmitting  
 PR - Power Consumption for Receiving  
 PA(d) - Power Consumption of the Power Amplifier

And PTB, PTRF, PRB, PRRF and PL do not depend on the transmission range.

The **power supply module** of the nodes is related to the manufacturer and the model of each node.

### 1.3 WSN Routing Challenges and Design Issues

Despite the huge applications of WSNs, these networks have several restrictions like limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network. The design of routing protocols in WSNs is influenced by many challenging factors and all these factors must be overcome before efficient communication can be achieved in WSNs.

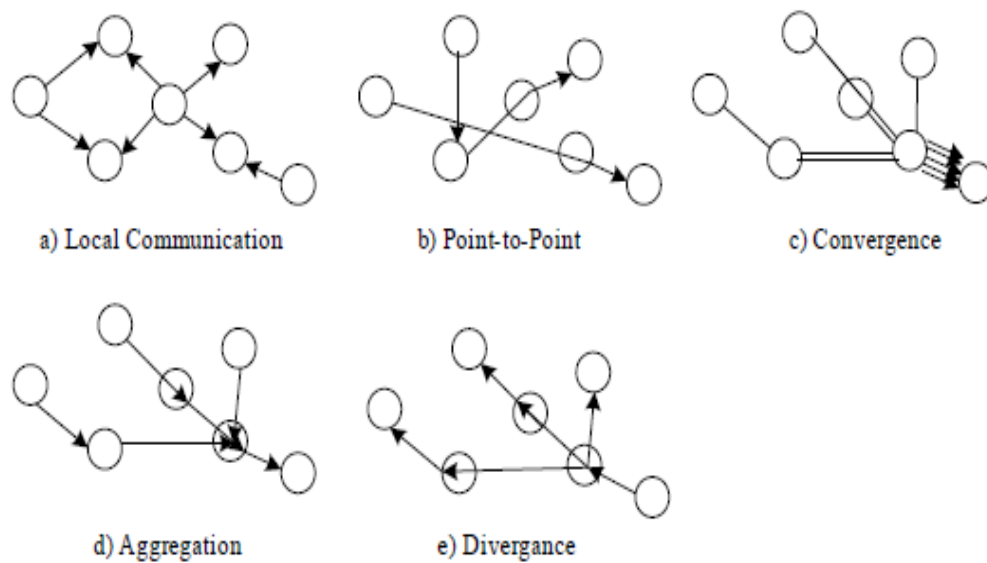
**Table 1.1 Challenging Factors in Routing**

Sr. No.	Challenging Factor	Routing Impact
1.	<b>Node Deployment</b>	Affects Performance of Routing Protocols in either deterministic or randomized manner.
2.	<b>Data Reporting Model</b>	Routing protocol is highly influenced by the data reporting model with regard to energy consumption and route stability.
3.	<b>Fault Tolerance</b>	Multiple levels of redundancy may be needed in a fault-tolerant sensor network.
4.	<b>Data Aggregation</b>	The data gathered from each node are correlated. Therefore Data fusion decreases the size of the data transmitted.
5.	<b>Quality of Service (QoS)</b>	The total Network Lifetime should be shortened to attain the quality of Data sent.

### 1.4 Traffic Patterns in WSNs

In difference to traditional networks, the WSNs exhibit unique asymmetric traffic patterns. This is mainly due to the functions of the WSN which are to collect data; sensor nodes persistently send their data to the base station, while the base station only occasionally sends control messages to the sensor nodes. Moreover, the different applications can cause a wide range of traffic patterns. The traffic of WSNs can be either single hop or multi-hop. The multi-hop traffic patterns can be further divided, depending on the number of sending and receiving nodes, or whether the network supports in network.

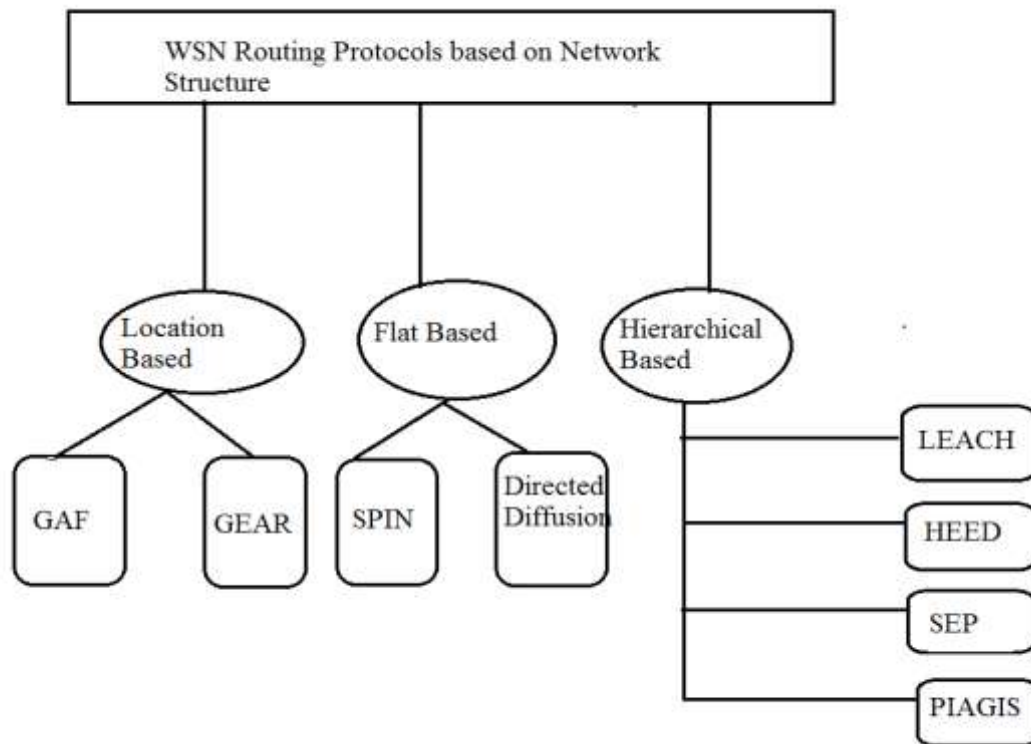
This asymmetric traffic pattern of WSN is shown in the fig. 1.5.



**Fig: 1.4 Traffic patterns in WSNs**

### 1.5 WSN Routing Protocols

The WSN Routing Protocols based on Network Structure are broadly classified in three categories as shown in the Fig 1.5



**Fig. 1.5 WSN Routing Protocols based on Network Structure**

### 1.5.1 Location Based Routing Protocols

In recent years, many useful location based routing protocols have been developed for sensor networks. Well known location-based protocols are: Geographic Adaptive Fidelity (GAF) and Geographic and Energy Aware Routing (GEAR).

### 1.5.2 Flat Based Routing Protocols

In flat based networks, each sensor node typically plays the same role and sensor nodes collaborate together to perform the sensing task. Due to the large number of such sensor nodes, it is not feasible to assign a global identifier to each node. This consideration has led to data centric routing, where the base station send queries to certain regions and then wait for data from the sensor nodes located in that selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data.

### 1.5.3 Hierarchical Based Routing Protocols

Hierarchical routing protocols are also known as cluster-based routing, proposed in wireless networks. They are well known techniques having special advantages related to scalability and efficient communication and energy efficient routing in WSNs. In a hierarchical architecture, higher energy nodes are used to process and send the information while low energy nodes are used to perform the

sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way for lowering energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the remaining layer is used for routing.

### 1.6 The SEP Protocol

SEP, which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, named as the fraction of advanced nodes ( $m$ ) and the additional energy factor between advanced nodes and normal nodes ( $\alpha$ ). Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fair constraint on energy consumption. On the other hand, the total energy of the system changed. Suppose that  $E_0$  is the initial energy of each normal sensor. The energy of each advanced node is then  $E_0 \cdot (1+\alpha)$ . The total (initial) energy of the new heterogeneous setting is given by:

$$n \cdot (1 - m) \cdot E_0 + n \cdot m \cdot E_0 \cdot (1 + \alpha) = n \cdot E_0 \cdot (1 + \alpha \cdot m) \quad (5)$$

So, the total energy of the system is increased by a factor of  $(1+\alpha \cdot m)$ . In order to optimize the stable region of the system, the new epoch must become equal to  $1 \cdot p_{opt} \cdot (1+\alpha \cdot m)$  because the system has  $\alpha \cdot m$  times more energy and virtually  $\alpha \cdot m$  times more nodes (with the same energy as the normal nodes.) We can now increase the stable region of the sensor network by  $1+\alpha \cdot m$  times, if

- (i) each normal node becomes a cluster head once every  $1 \cdot p_{opt} \cdot (1+\alpha \cdot m)$  rounds per epoch;
- (ii) each advanced node becomes a cluster head exactly  $(1 + \alpha)$  times every  $1 \cdot p_{opt} \cdot (1+\alpha \cdot m)$  rounds per epoch; and
- (iii) The average number of cluster heads per round per epoch is equal to  $n \times p_{opt}$  (since the spatial density does not change.)

### 1.7 HETEROGENEOUS WSN MODEL

The heterogeneous wireless sensor network model includes cluster formation and maintains the optimum number of clusters.

#### 1.9.1 Creation of a cluster

The Low Energy Adaptive Clustering Hierarchy (LEACH) is a protocol which is hierarchically clustered where each cluster is re-established in each round. In this protocol, new cluster heads get elected in each round and as a result of this 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. To decide whether a node is to become cluster head or not a threshold value  $T(s)$  is addressed in, which is as follows:

$$T(s) = \left\{ \begin{array}{l} \frac{P_{opt}}{1 - P_{opt} \cdot (r \bmod \frac{1}{P_{opt}})}, \text{ if } s \in G' \\ 0, \text{ otherwise} \end{array} \right\} \quad (1)$$

Where  $r$  is the current round number and  $G$  is the set of nodes that have not become cluster heads 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 will become a cluster head in the current round.

### 1.7.2 Optimum number of clusters

In order to achieve an acceptable SNR in transmitting  $L$  bit message over a distance  $d$ , the energy dissipation by the radio is given by:

$$E_{Tx}(l, d) = \left\{ \begin{array}{l} L \cdot E_{Elec} + L \cdot \epsilon_{fs} \cdot d^2, \text{ if } d \leq d_0 \\ L \cdot E_{Elec} + L \cdot \epsilon_{mp} \cdot d^4, \text{ if } d \geq d_0 \end{array} \right\} \quad (2)$$

- $E_{elec}$  - Energy Dissipated per Bit
- $\epsilon_{fs}$  - Free Space Fading
- $\epsilon_{mp}$  - Multipath Fading
- $d$  - Distance between a Cluster member Node and its Cluster Head

By equating the two expressions at  $d = d_0$ , we get

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \quad (3)$$

The optimum number of clusters  $k_{opt}$  for the cluster based network, having  $n$  sensor nodes distributed randomly in a  $(M \times M)$  sensor field is as follows:

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

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

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

### 3. Proposed Algorithm:

In proposed protocol, the following assumption are to be considered.



- A fixed base station is located in the middle of the region.
- The nodes are equipped with power control capabilities to vary their transmitted power.
- Each node senses the environment at a fixed rate and always has data to send to the base station.
- All sensor nodes are immobile.

The radio channel is supposed to be symmetrical. Moreover, it is assumed that the communication environment is contention and error free. Hence, there is no need for retransmission.

A percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let  $m$  be the fraction of the total number of nodes  $n$ , which are equipped with  $\alpha$  times more energy than the others. We refer to these powerful nodes as advanced nodes, and the rest  $(1-m) \times n$  as normal nodes. Suppose that  $E_0$  is the initial energy of each normal sensor. The energy of each advanced node is then  $E_0 \cdot (1+\alpha)$ . The total (initial) energy of the new heterogeneous setting is equal to:

$$n * E_0 * (1 + \alpha * m)$$

So, the total energy of the system is increased by a factor of  $1 + \alpha * m$ .

- each normal node becomes a cluster head once every  $1/p_{opt} \cdot (1+\alpha \cdot m)$  rounds per epoch;
- each advanced node becomes a cluster head exactly  $1 + \alpha$  times every  $1/p_{opt} \cdot (1+\alpha \cdot m)$  rounds per epoch;
- the average number of cluster heads per round per epoch is equal to  $n \times p_{opt}$

Cluster Head Election for normal nodes is based on following equation:

$$T(s_{nrm}) = \begin{cases} \frac{p_{nrm}}{1 - p_{nrm} \cdot (r \bmod \frac{1}{p_{nrm}})} & \text{if } s_{nrm} \in G' \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where  $r$  is the current round,  $G'$  is the set of normal nodes that have not become cluster heads within the last  $1/p_{nrm}$  rounds of the epoch, and  $T(s_{nrm})$  is the threshold applied to a population of  $n \cdot (1 - m)$  (normal) nodes. This guarantees that each normal node will become a cluster head exactly once every  $1/p_{opt} \cdot (1+\alpha \cdot m)$  rounds per epoch, and that the average number of cluster heads that are normal nodes per round per epoch is equal to  $n \cdot (1 - m) \times p_{nrm}$ .

Cluster Head Election for advanced nodes is based on following equation:

$$T(s_{adv}) = \begin{cases} \frac{p_{adv}}{1 - p_{adv} \cdot (r \bmod \frac{1}{p_{adv}})} & \text{if } s_{adv} \in G'' \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

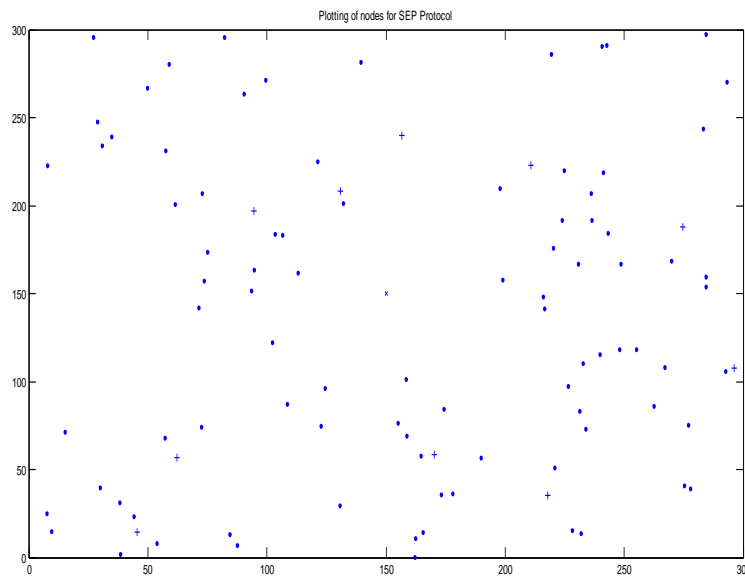
where  $G''$  is the set of advanced nodes that have not become cluster heads within the last 1

$p_{adv}$  rounds of the epoch, and  $T(s_{adv})$  is the threshold applied to a population of  $n \times m$  (advanced) nodes. This guarantees that each advanced node will become a cluster head exactly once every  $(1/p_{opt}) \times ((1+\alpha \cdot m)/(1+\alpha))$  rounds.

#### 4. Experimental Results:

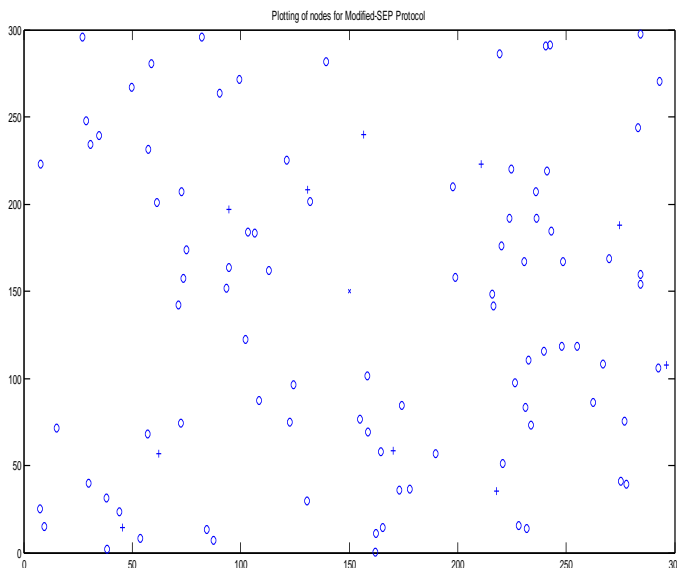
Sr.No.	Parameters	Values
1	Network Field	300x300
2	n (Number of Nodes)	100
3	Initial Energy	1 Nano Joule
4	$E_{elec}$ (E.Dissipation for $E_{Tx}$ & $E_{Rx}$ )	50 nJ/bit
5	$\epsilon_{fs}$ (free space)	10 pJ/bit/m <sup>2</sup>
6	$\epsilon_{mp}$ (Multipath fading)	0.0013 pJ/bit/m <sup>4</sup>
7	EDA(Energy Aggregation Data)	5 nJ/bit/signal
8	Data packet size	3000
9	Tool used for implementation	MATLAB 2010
10	No. of Rounds	2000

As shown in Fig 4.1 below, plotting of nodes for SEP protocol with Probability of a node to become a cluster head is 0.1 and energy supplied to each node is 0.5.



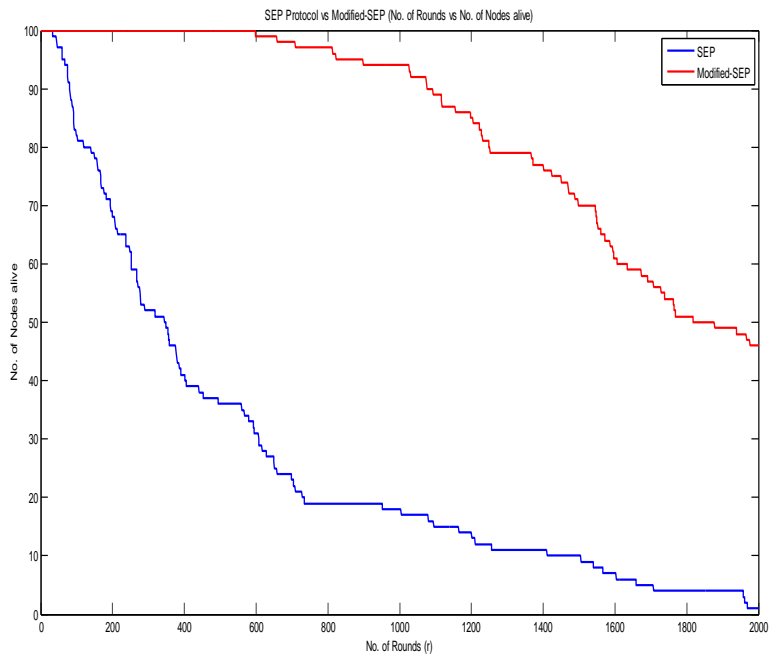
**Fig. 4.1 Plotting of Nodes for SEP Protocol**

Fig. 4.2 shows the plotting of nodes for M-SEP under the same conditions used for SEP protocol in Fig 4.1.



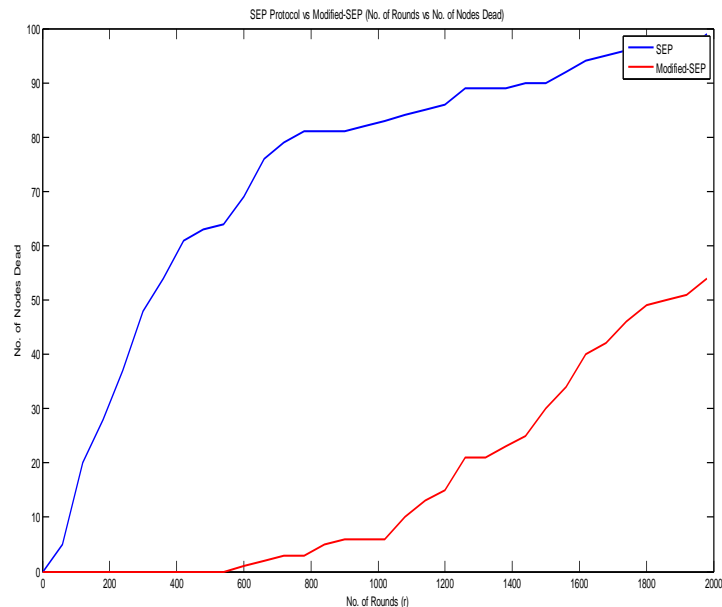
**Fig 4.2 Plotting of Nodes for M-SEP**

Fig 4.3 show the lifetime of the network is increased in modified SEP as compared to SEP Protocol. Nodes show much stability in M-SEP as compared to SEP and hence, increases the network lifetime.



**Fig 4.3 Plotting of no. of rounds vs no. of Nodes alive**

Refer Figure 4.4 below, it shows the comparison between no. of dead nodes versus no. of rounds in SEP Protocol and modified SEP as well. As we can see in Fig 4.4, no. of dead nodes is comparatively less in M-SEP as compared to SEP protocol as the number of rounds increases.



**Fig 4.4 Plotting of No. of rounds Vs no. of Nodes Dead**

## 5. Conclusion and Future Work:

In this work, the author reviews the Stable Election Protocol and Modified-Stable Election Protocol on the system software in heterogeneous network and also compared the number of live nodes & dead nodes with SEP protocol as well as with M-SEP. Since we have implemented M-SEP as an energy efficient routing, but there is no security. In future, we can enhance this protocol to secure the routing of data in Wireless Sensor Networks (WSN).

## 6. References:

- [1] Al-Karaki & Kamal, A., “Routing Techniques in Wireless Sensor networks: A Survey,” *Security and Networks*, Vol. 11, Issue 6, pp. 6-28, 2014.
- [2] Lu, H., “Secure and Efficient Data Transmission for Cluster-Based Wireless Sensor Networks”, *IEEE Trans.on Parallel and Distributed Systems*, Vol. 25, No. 3, 2014.
- [3] Toldan, P. & Kumar, A. A., “Design Issues and Various Routing Protocols for Wireless Sensor Networks (WSNs)”; *Proceedings of National Conference on New Horizons in IT – NCNHIT*, 2013.

- [4] Singh, S. & Singh, K., “Energy efficient election probability and cluster head selection for enhancement of SEP-E in wireless sensor networks”, Machine Intelligence and Research Advancement (ICMIRA), ., E.C.E. Dept., G.N.D.E.C., Ludhiana, India, 2013.
- [5] Tripathi, M. et al., “LEACH-C protocol for Wireless Sensor Network,”Computational Intelligence and Information Technology, Malaviya Nat. Inst. of Technol., Jaipur, India, 2013.
- [6] Ehsan, S. & Hamdaoui, B., “A Survey on Energy-Efficient Routing Techniques with QoS Assurances for Wireless Multimedia Sensor Networks,” *IEEE Commun. Surveys Tuts.*, Vol. 14, Issue 2, pp.265-278, 2011.
- [7]Elbhiri, B., et. al., “Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks”, IEEE 2010.
- [8] G. Haosong & Y. Younghwan, “An Energy Balancing LEACH Algorithm for Wireless Sensor Networks”, Seventh International Conference on Information Technology (IEEE) , LasVegas, NV, pp.822-827, April 12-14, 2010.
- [9] Yadav, R., Varma, S., & Malaviya, N., “A Survey of MAC Protocols for Wireless Sensor Networks,” *UbiCC Journal*, Vol. 4, Issue 3, pp. 827-833, 2009.
- [10] Biradar, R. V., et al., “Classification and Comparison of Routing Protocols in Wireless Sensor Networks,” *Special Issue on Ubiquitous Computing Security Systems*, Vol. 4, Issue 2, pp. 704-711, 2009.