Modified Enhanced Threshold Sensitive Stable Election Protocol using Firefly Algorithm for Heterogeneous Wireless Sensor Network

[1]Supreet Kaur, [2]Dr. Rajeev Kumar

[1]Student, Computer Science Engineering, DAV Institute of Engineering and Technology, Jalandhar, INDIA
[2]Assistant Professor, Computer Science Engineering, DAV Institute of Engineering and Technology, Jalandhar, INDIA

Abstract: Wireless Sensor network faces major challenges like energy consumption, network lifetime and Stability of the network. Clustering is one of the best methods to reduce the energy conservation. In this paper we propose Enhanced Threshold Sensitive Stable Election Protocol Using Firefly Algorithm (ETSSEP-FF). ETSSEP-FF is reactive protocol that uses three levels of heterogeneity. This Paper is based on ETSSEP protocol. It performs the process of CH election on the basis of probability of the node. Then it used the Firefly algorithm for the routing from cluster head to Base Station. The firefly algorithm is based on the attractiveness of firefly. In results simulation is done in MATLAB and ETSSEP-FF performs better than ETSSEP and SEP protocol.

Keywords: **Heterogeneity, Stability, Instability, Firefly algorithm**.

I. INTRODUCTION

Wireless sensor network (WSN) consists of small size sensor nodes used for data gathering applications. These nodes analyse external environmental conditions, like weather changes, temperature, vibrations, movements, pressure and noise. To achieve highly efficient data, a sensor network places the number of sensor nodes which are unsystematically placed inside the area of interest [7]. The nodes of the sensor network take the data from the environment and forward that to the centre location called base station (BS). The major restriction of WSN is that the nodes have limited energy and their battery cannot be replaced and recharged. For increasing the network lifespan and effectively managing network energy consumption various techniques have been developed.

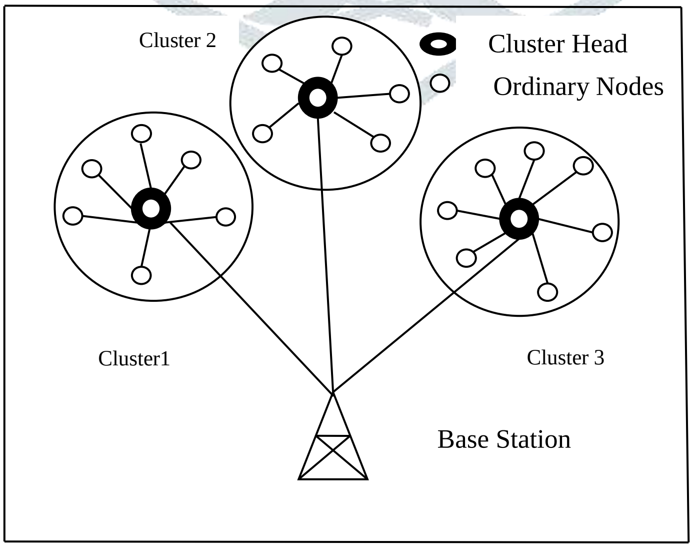

Fig. 1 Clustering in Wireless Sensor Network

Among all the techniques, Clustering is widely accepted for its excellent energy saving property and adaptability. [11]When network is divided into number of sensor group called cluster, that grouping of nodes is known as clustering technique. Fig 1 shows each cluster consists of Cluster Head (CH) and other nodes are called members or ordinary nodes. The ordinary node collect data packets and send that to its corresponding CHs, then cluster head combines the received data into one packet and then forwarded the collected packet to the final destination that is known as Base Station (BS). BS can be placed within the network or at another place [5].

In this study we designed a heterogeneous network that have three different levels of nodes are advance nodes, intermediate nodes, and normal nodes. This paper is based on ETSSEP protocol. In addition with ETSSEP we used the firefly algorithm for routing of CH's. The CH takes data from the ordinary nodes and transfers that data to the sink. Firefly finds the best path from CH to BS to transmit the data packets. Fireflies attract from the brighter firefly. So that in term of nodes fireflies move forward to the node that has more energy.

In remainder of paper sections are organized as: Section 2 includes the related work. Radio energy model is described in section 3. Section 4 includes details about ETSSEP-FF. Section 5 has simulation and discussion. And last section describe conclusion.

II. RELATED WORK:

In paper [2] Heinzelman et. Al. presents (LEACH). LEACH assumes that the energy consumes by the nodes with respect to the energy consumed by the network is homogeneous. In this research, CHs selection is performed in every round, and then the ordinary nodes give data packets to the corresponding CHs. The CH combines the information taken from the nodes and compress that data, then forward that data to the sink or BS. This process of data transferring decrease the consumption of energy because data forwarding to the sink is only done by the CH.

In this paper Arati Manjeshwar et. al. [3] presents TEEN (Threshold sensitive Energy Efficient protocol). It uses the two threshold values for data transmission process that are Hard Threshold and Soft Threshold. These are threshold values of sensed attribute. Hard Threshold is absolute and Soft Threshold is small change in the value of sensed attribute.

In this paper [3] G. Smaragdakis et. al. presented a heterogeneity aware protocol SEP (Stable Election Protocol). SEP includes two levels oh heterogeneity. In SEP each node becomes CH according to weighted election probability of that node. The parameter used for heterogeneity are, the fraction of advance nodes is m and the difference of energy between advance and normal nodes is define by $\alpha . pbnrm = \frac{pbopt}{1+m.\alpha}$ is define the possibility of advance nodes to became cluster head and $pbadv = \frac{pbopt.(1+\alpha)}{1+m.\alpha}$ is define the probability of normal node to become CH. The threshold equation is used to for the advance node and normal node.

$$Th_{(S)} = \begin{cases} \frac{pb}{1-pb.(r \bmod \frac{1}{pb})} & if\ s \in S \\ 0 & otherwise \end{cases} \quad (1)$$

Femi A. Aderhunmu et. al.[4] proposed a new protocol SEP-E. It is extension of SEP (Stable Election Protocol). In this paper new nodes are introduced called intermediate nodes which acts as bridge between the advanced and normal nodes. The intermediate nodes have the more energy than the normal node and have the less energy than the advanced node.

Brahim Elbhiri et. al. [5] presents a extension of DEEC protocol is DDEEC. In DEEC the advanced nodes have more possibility than normal nodes to become CH. To avoid this problem of DEEC protocol, the DDEEC introduced some changes by using Threshold Residual Energy ValueTh_{RE}. With the use of Th_{RE}, the advanced nodes and normal nodes have the same probability to become CH.

Mukhdeep Singh Manshahia et. al. [13] presents a paper on clustering using firefly algorithm. In this paper, firefly algorithm is used for the clustering of nodes. Firefly algorithm used the fitness function for the clustering of nodes. That fitness function is derived from the two parameters that are distance and residual energy. For calculation of fitness function distance between the nodes and node's remaining energy is used. Fireflies are work on the phenomenon of bioluminescence process. Fireflies insect are mainly based on the intensity of light.

Praveen Lalwani et. al. proposed the energy efficient firefly algorithm for routing in WSN. In this paper, fireflies are used to provide the best path from the CH to the BS. By using firefly algorithm, it finds the shortest information for transfer the data from CH to sink. Firefly algorithm used the fitness function for the clustering of nodes. That fitness function is derived from the two parameters that are distance and residual energy and average energy. For calculation of fitness function node's distance, node's remaining energy and degree of node is used. Fireflies attract from brightness of the light. In case of energy, fireflies attract from the energy of the other node. It moves forward to the node that has more energy.

III. RADIO ENERGY DISSIPATION MODEL:

Radio Energy model used in this paper is taken from [14]. It describes that 1-bit data is transmitted over a distance d. Where k is number of bits, E_{elec} is energy used to transmit the electronics over the distance d. Working of energy model is given in Fig 2. The distance and power switch can be fixed by the radios [7,8]. The following radio energy dissipation model is used to transfer specific message over distance d.

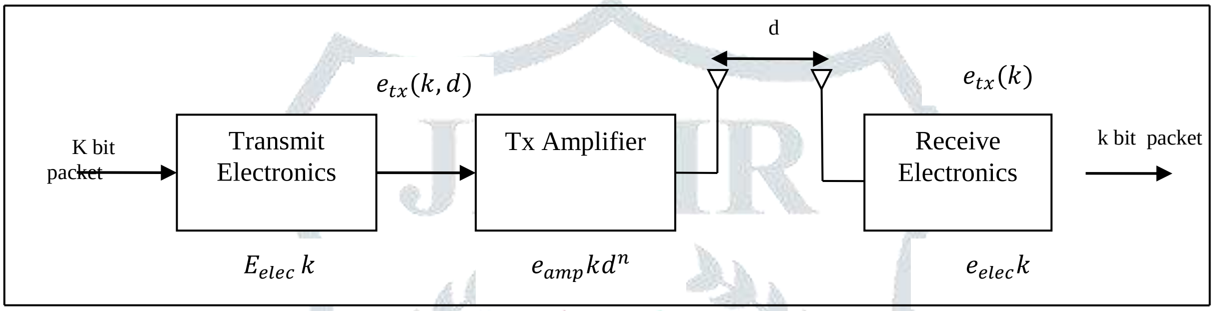

Fig 2. Radio Energy Dissipation Model

$$e_{TX}(k,d) = \begin{cases} K * e_{elec} + K * e_{fs} * d^2, if\ d < d_o \\ K * e_{elec} + K * e_{amp} * d^4, if d \geq d_o \end{cases} \quad (2)$$

e_{elec} is electronics energy, whereas the amplifier energy is $e_{fs}.d^2$ and $e_{amp}.d^4$. Free space model (fs) and multipath model (amp) used on the behalf of threshold distance d_0. The energy dissipation is shown in Fig 2.

The value of d_o is given by:

$$d_o = \frac{e_{fs}}{e_{amp}} \quad (3)$$

Energy dissipation for receiving K bits E_{Rx} is estimated as:

$$e_{Rx}(K) = K.e_{elec} \quad (4)$$

IV. THE PROPOSED ETSSEP-FF

ETSSEP-FF protocol is discussed in this section. It is modification of ETSSEP Protocol [11]. ETSSEP-FF is a reactive protocol that is based on the clusters. It includes the three level of heterogeneity. The different level of heterogeneity nodes are advance nodes, intermediate nodes and normal nodes. Initially higher amount of energy is allotted to advance nodes and lower amount of energy is allotted to normal nodes. Energy allotted to the intermediates nodes is between advance nodes and normal nodes. β is used to describe the additional energy factor of Advance nodes than normal nodes and γ is used to describe the additional energy factor of intermediates nodes. Then we calculate the value of $\gamma = \beta/2$. The below given equations are used to calculate the initial energy to the different nodes.

For normal nodes,

$$e_{nrm} = n.f.(1+\gamma) \quad (5)$$

For intermediate nodes,

$$e_{int} = n.(1 - fn - m).E_0 \quad (6)$$

For Advanced nodes,

$$e_{adv} = n.m\,(1+\beta).E_0 \tag{7}$$

Total energy e_{Total} of the different nodes is calculated as

$$e_{Total} = n.(1-fn-m).E_0 + n.f.(1+\gamma) + m.n(1+\beta).E_0$$
$$= n.E_0(1+f.\gamma+m.\beta) \tag{8}$$

In this equation n describe the total no. of nodes, m describe the fraction of advance nodes and f describe the fraction of intermediate nodes. ETSSEP-FF calculates the probability of nodes based on remaining energy of the node and at particular round r network's average energy. To calculate the $\bar{e}$(r) network's average energy of particular round r:

$$\bar{e}(\mathrm{r}) = \frac{1}{N} e_{total}(1-\frac{r}{R}) \tag{9}$$

In this equation N represents total number of heterogeneous nodes, e_{total} represents total initial energy of the network, r is used to denote the current round and Rd is used for the total rounds. Rd is calculated as

$$Rd = \frac{e_{total}}{e_{round}} \tag{10}$$

e_{round} denotes the energy consume in the network in a particular round. e_{round} can be calculated as:

$$e_{round} = K(2Ne_{elec} + NE_{DA+}kE_{amp}d^4{}_{toBS} + NE_{fs}\,d^2{}_{toCH}) \tag{11}$$

In this equation, K represents size of data, E_{DA} denotes the energy consumed in data aggregation, k represents the number of clusters, d_{toBS}[11] denotes the distance from CH to sink, d_{toCH}[11]represents the distance from CH to ordinary nodes.

$$d_{toBS} = 0.765\frac{M}{2} \tag{12}$$

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}} \tag{13}$$

The process of CH election is mainly depends on the probability of every node. The node with the higher probability has more chances to become CH. For three levels of heterogeneity, the probabilities of different nodes are calculated as follows:

For normal nodes

$$pb_{nrm=}\frac{P_{opt}}{1+m.\beta+f.\gamma} \tag{14}$$

For Intermediate nodes

$$pb_{int=}\frac{pb_{opt}(1+\gamma)}{1+m.\beta+f.\gamma} \tag{15}$$

For advance nodes

$$pb_{adv=}\frac{pb_{opt}(1+\beta)}{1+m.\beta+f.\gamma} \tag{16}$$

In these equations n is defined as total no. of nodes, fraction of advance nodes is m to the n and fraction of intermediate nodes is f to the n. Initially when round starts every node has possibility to reform as CH. Same node cannot be elected as CH in a same epoch, if it is already elected as CH in the current round. For the process of CH election, threshold parameter is taken into account. Every node produced random number between 0 and 1, if threshold is higher than this produced number than the node will reform as cluster head. Otherwise it will become an ordinary node. The threshold value is calculated as:

$$Th_{(S)}\begin{cases}\frac{pb}{1-pb[r.mod\frac{1}{pb}]} * \frac{node's\ residual\ energy}{network's\ Average\ energy * K_{opt}} & if\ s\ \in S\\ 0 & otherwise\end{cases} \tag{17}$$

For different nodes:

$$Th_{nrm=}\begin{cases}\frac{pb_{nrm}}{1-P_{nrm}[r.mod\frac{1}{pb_{nrm}}]} * \frac{e_r}{e_{an}*K_{opt}} & if\ n_{nrm}\ \in S'\\ 0 & otherwise\end{cases} \tag{18}$$

$$Th_{int=}\begin{cases}\frac{Pb_{int}}{1-pb_{int}[r.mod\frac{1}{pb_{int}}]} * \frac{e_r}{e_{ai}*K_{opt}} & if\ n_{int}\ \in S''\\ 0 & otherwise\end{cases} \tag{19}$$

$$Th_{adv} = \begin{cases} \frac{pb_{adv}}{1-pb_{adv}[r.mod\frac{1}{pb_{int}}]} * \frac{e_r}{e_{aa}*K_{opt}} & if\ n_{adv} \in S''' \\ 0 & otherwise \end{cases} \quad (20)$$

In these equations K_{opt} is used for optimal number of clusters. S', S'', S''' denotes the group of normal nodes, intermediate nodes, advance nodes respectively that have not reform as CH. Th_{nrm},Th_{int}, Th_{adv} are the threshold values for the normal, intermediate and advance nodes respectively. e_r denotes the residual energy of the current node.

4.1 Routing Using Firefly Algorithm:

In this paper we use Firefly algorithm for routing. It finds the best route each CH to BS. In routing using firefly algorithm, every firefly represents the path for data transfer from every CH to BS. Firefly insect produce flashes and follow the flash lights of each other. The process of producing flash lights is called bioluminescence. Intensity of flash is important parameter for the other fireflies. The firefly algorithm works on the basis of three rules:

1. Fireflies of any gender can attract towards the other firefly.
2. Fireflies attract from the other fireflies with brightness of the flash.
3. Objective function helps to determine the brightness of fireflies.

The numbers of fireflies is equal to the quantity of CH's used in the network and one more position is added to the BS. So the number of fireflies is equal to$k + 1$, where k represents the no. of CHs and 1 represents the BS. To find the best route using firefly algorithm, it uses the fitness function that consists of distance, CH's residual energy, and network's average energy.

Derivation of Fitness Function: Firefly algorithm works on the basis of fitness function. For optimal path from CH to BS firefly algorithm is used. To achieve this, fitness function is derived as follows:

(i) Residual Energy of next Hop: For data transfer, next hop receive and combines information and transfer it to BS. So according to firefly algorithm, next hop with the higher energy is preferable choice to send data. So we calculate the residual energy $f1$ as:

$$f1 = \sum_{i=1}^{n} e_{CHi} \quad (21)$$

(ii) Euclidean Distance: The distance from CH to next hop and from there to BS. For lower consumption of energy, the distance should be less than it. Formula to calculate the euclidean distance $f2$:

$$f2 = \frac{1}{\sum_{i=1}^{n} d(CHi,NH)+(NH,BS)} \quad (22)$$

(iii) Average Energy of the network: It is the overall average energy of the network. It can be calculated as:

$$\text{Average Energy} = \frac{1}{N} e_{total}(1 - \frac{r}{R}) \quad (23)$$

$$\text{Fitness} = \alpha1f1+\alpha2f2+\alpha3f3 \quad (24)$$

Where α1, α2, α3 are the weights given to algorithm, where αi ε(0,1) and α1+α2+α3=1

4.1.1. Structure of Firefly Algorithm:

Firefly Algorithm:

1) Start:

2) Initiate all variables:

3) f(x) : objective function, i.e. x=(x1,........,xz)

4) Initialize fireflies xm (m=1,2 ,..., n)

5) Calculate the Intensity of Light of current node Ii at xm

6) While (l <MAXGen), where MAXGen is max generations

7) for p = 1 : n

for q=1 : n

If (Iq> Ip),

Firefly p : q

end if

8) Attractiveness =Exp [-αr2],

Where r denotes distance between fireflies α denotes light absorption Coefficient

9) Update the node's light intensity

10) end for q;

11) end for p;

12) end while;

The attractiveness (intensity of flash light) is inversely proportional the distance. When the distance increases the light intensity is decreases and when distance decreases then light intensity increases.

$$I(n) = I_0\, e^{\wedge}(-\beta d_{ij}{}^{\wedge}(2)) \quad (25)$$

Where, I denotes the light intensity

I_0 denotes its initial value

β denotes light absorption coefficient

d denotes distance between firefly p and q

The values of residual energy of node, average energy of network and distance between the nodes are given to the objective function. For the routing of nodes, a fitness value is calculated. The light intensity formula as given in Eq. 24 is used for calculating the light intensity value.

V. SIMULATION AND RESULTS:

For ETSSEP-FF protocol simulation is performed in Matlab tool. The experiment is performed with the 100 nodes in 100 m × 100 m area of network. We compare the simulation results with ETSSEP-FF with SEP and ETSSEP on the behalf of network longevity and throughput.

Various parameters used in simulation are:

1. Network lifetime: is time period from start of the network to end of the network.
2. Stability Period: when nodes start transmitting data to the first node death.
3. Instability period: is the period from first node death to the death of the last node.
4. Throughput: throughput defines with number of packets move to the BS till the end of the network.

Parameters used in simulation are written in Table1. The initial energy provides to the nodes is 0.5J. The size of the data packet is 4000 bits. Energy used for transmitter and receiver circuitry is 50nJ/bit. pb_{opt} is optimal probability for choosing the CH.

Table 1: Parameter used in network

Parameter	Values
Area of Network	100,100
Nodes	100
Initial energy(E_o)	0.5J
Size of message	4000 bits
e_{elec}	50nJ/bit
E_{fs}	10nJ/bit/m^2
E_{amp}	0.0013pJ/bit/m^2
E_{Da}	5nJ/bit/signal

Pb_{opt}	0.1
γ	2
m	0.1

The fig. 3 shows the network throughput i.e. the no. of packets transfer by the network in no. of rounds. As given in Fig. 3 ETSSEP-FF performs better than other protocols because routing of CHs is done by the firefly algorithm. With ongoing improvement of the algorithm by using the parameter average energy to calculate the fitness function, that improve the efficiency of ETSSEP-FF and also ETSSEP-FF the protocol consumes less energy than other protocols. ETSSEP-FF sends the 21000 packets and ETTSSEP and SEP sends the 16000 and 7000 packets in the same no. of rounds.

Fig 4 shows the lifetime of the network i.e. time period from start of the network to end of the network. The lifetime of the network is 1590, 2500 and 2590 for SEP, ETSSEP, ETSSEP-FF respectively.

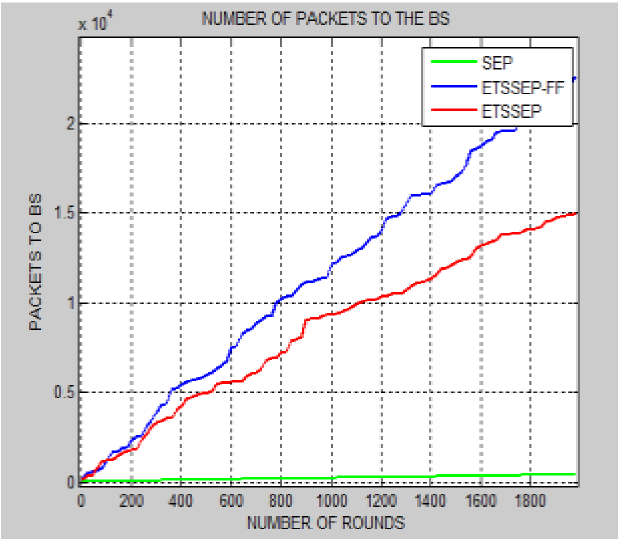

Fig. 3 Throughput of Protocols

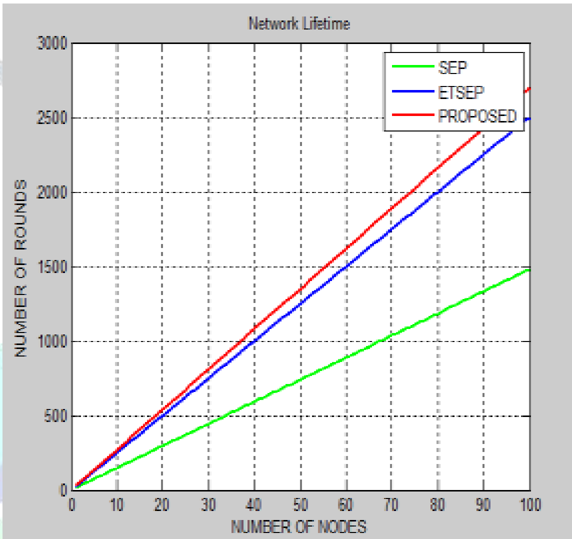

Fig. 4 Network Lifetime

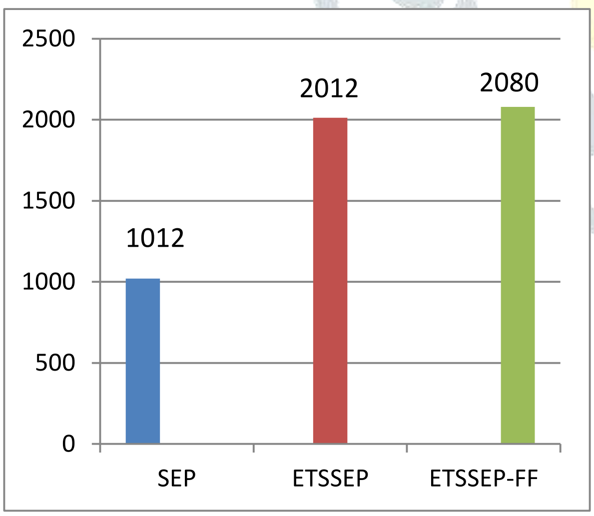

Fig 4.a First Node Die

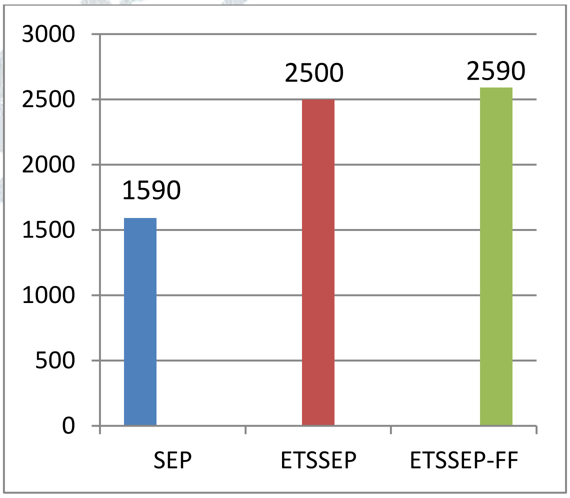

Fig. 4.b Last Node Dead

Fig 4.a shows the result of first node dead at which round. Fig 4.b shows the results about the last node dead. The results of the ETSSEP-FF are better than other protocol because of additional parameter used in firefly algorithm for the fitness function that is Average energy.

Fig 5 shows the stability of the network. It shows that ETSSEP-FF, ETSSEP, SEP first node of protocol is dead at 2080 and 2012 and 1019 round respectively. It simply shows that the ETSSEP_FF performs better than the other two protocols because for the routing CH's firefly algorithm is used.

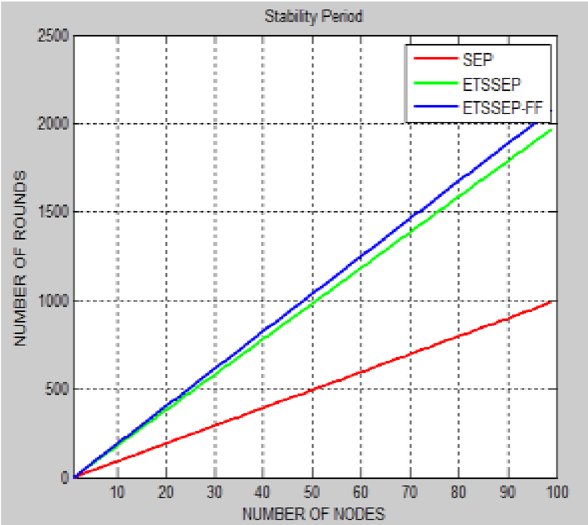

Fig. 5 Stability Period of Network

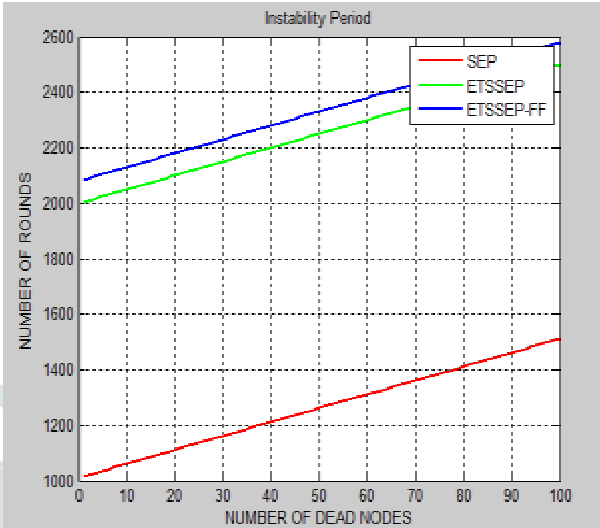

Fig. 6 Instability Period of Network

ETSSEP-FF instability period of network is increased that is shown in Fig 6. Instability of network is the period from first node death to the death of the last node. The instability period of ETSSEP-FF 2080 to 2590 rounds, ETSSEP 2012 to 2500 round, and SEP 1012 to 1590 rounds. It simply shows that ETTSSEP-FF also performs better than other protocols because with use of firefly algorithm, energy consumption by the CH is reduced.

VI. CONCLUSION

In this research, routing protocol for energy efficient (ETSSEP-FF) for heterogeneous networks was presented. In WSN network lifetime, stability, instability and energy consumption are the major issues. In ETSSEP-FF we used the firefly algorithm that enhances the performance of ETSSEP. ETSSEP-FF shows better results as compared to ETSSEP and SEP. ETSSEP-FF enhances the stability period and network lifetime.

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