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Energy Efficient Routing Algorithm for Maximizing Network Lifetime of Heterogeneous Wireless Sensor Networks

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ABSTRACT: In today's scenario there has been increasing interest in the field of Wireless Sensor Networks (WSNs). One of the main issues of WSNs is development of energy efficient routing protocols. Clustering scheme is an efficient method used in WSNs to increase energy efficiency. In this scheme, heterogeneous protocols consider two or three energy level of nodes. But in real life purpose there is high range of energy levels in heterogeneous WSNs. Due to this variation we propose the higher version of BEENISH which is TSA-BEENISH (Threshold Sensitive Advanced Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol) using with TEEN protocol to increase the stability and life time of the network. Here, Cluster Heads (CHs) are selected on the bases of residual energy level of nodes. From simulation result it is shown that TSA-BEENISH performs better than existing protocols BEENISH (Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol), Distributed Energy Efficient Clustering (DEEC), Developed DEEC (DDEEC) and Enhanced DEEC (EDEEC) in terms of stability, effective packet sending and lifetime.

KEYWORDS: CH, Heterogeneous, Residual Energy, Energy Efficiency, WSNs

I. Introduction

A wireless sensor [2] is not only performs sensing task but also perform processing, communication and storage. In technical word, a sensor is a hardware device that converts happen what may in the environment or physical instant into signals that can be analyzed. Energy consumption [1] is the main point for the operation of WSNs. For application purposes it is practically impossible to replace the batteries of the sensor networks. Because of the limited battery power due to this network lifetime of the network is limited. The power is a deficient resource in WSNs because of size and cost limitations of sensor nodes. Wireless sensor networks [2] have different types of applications. These are environment monitoring, target tracking, water, oil, structural health monitoring, agriculture, volcano monitoring, transportation, diagnosis, and underground mining, etc.

For cluster formation efficient grouping sensor nodes is beneficial in minimizing the energy consumption. There are many energy efficient protocols are made on clustering scheme based [12,17,18]. In clustering scheme deployed sensors are elected CH and each cluster members are collect raw data from environment and transfer these data to its cluster head node. Cluster head node collects data from cluster member and sends it to the sink or base station. We can perform clustering scheme in two types of networks i.e. homogeneous and heterogeneous networks [4].

In homogeneous networks, nodes have same initial energy and in the heterogeneous networks, nodes have different initial energy. For homogeneous LEACH [16], PEGASIS [11], and HEED [7] protocol algorithms are designed. These protocols are unable to work efficiently in heterogeneous networks. All nodes are normal nodes in homogeneous networks. But in heterogeneous networks more energy nodes are inserted so design an algorithms SEP [4], DEEC [3], EDEEC [8], TDEEC [9], EDDEEC [6] and BEENISH [13]. SEP protocol is based on two levels, and it has normal and advanced nodes, so it cannot work properly for multilevel of energy networks. Low energy level allocated to normal and high level of energy allocation to advanced nodes. For multilevel of energy networks design algorithms are DEEC, DDEEC, EDEEC, TDEEC, EDDEEC and BEENISH. These are work proper in two levels. Here super nodes are added as extra nodes in three levels of heterogeneity. Super nodes have higher energy as compared to normal and advanced

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nodes. Ultra super nodes are added for four levels of heterogeneous network. These nodes have higher energy than all other type of nodesThis document is a template. An electronic copy can be downloaded from the conference website. For questions on paper guidelines, please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

II. RELATED WORK

In homogeneous WSNs, W.Heinzelman, et al. [16] introduced a clustering algorithm known as LEACH (Low Energy Adaptive Clustering Hierarchy) in which selection of cluster head node is based on the probability and threshold. LEACH does not perform well in heterogeneous network so a different protocol introduced named as SEP.

Manjeshwar and D.P. Agarwal [20] proposed a new energy efficient protocol named as Threshold Sensitive Energy Efficient Sensor Network protocol (TEEN). In this protocol hierarchical approach is used along with the data centric mechanism. The cluster head broadcasts two thresholds (hard and soft) energy values to the nodes. TEEN is suitable for time critical applications but not for those applications that require periodic reports because the user may not get information if any threshold does not reach.

In heterogeneous network, a protocol SEP (Stable Election Protocol) was proposed by G. Smaragdakis, et al. [4]. In this two levels heterogeneous network, every sensor node independently chooses itself as a head node based on its initial energy related to other nodes. This protocol is suitable only for two level energy nodes.

So a multilevel energy nodes protocol came into existence named as DEEC. L. Qing, et al. [5] proposed a protocol known as DEEC (Distributed Energy-Efficient Clustering). In DEEC, the probability of the ratio of residual energy of node and average energy of the network is the basis for CH selection. Since advanced nodes have higher energy than normal nodes, so advanced nodes will continuously become a head node and they will die soon than normal nodes. Since probability can be calculated using initial energy and average energy.

A protocol named as DDEEC (Developed DEEC) has introduced by B. Elbhiri, et al. [3]. To resolve the problem of energy distribution in DEEC, DDEEC makes some improvement in probability function to keep safe advanced nodes from being penalized again and again.

Parul Saini and A. K. Sharma [8] presented a protocol EDEEC (Enhanced DEEC) in which an extra amount of energy level node known as super node is added. EDEEC also penalize the advanced nodes and super nodes in the CH selection so this is not appropriate way for energy distribution. To overcome this problem, EDDEEC protocol came into existence.

Parul Saini and A. K. Sharma [9] presented a protocol TDEEC (Threshold DEEC) which elects the head node from the higher energy level nodes to improve energy efficiency and lifetime of the network. In this protocol energy can be saved with the help of a different threshold function.

N. Javaid, et al. [6] introduced a protocol EDDEEC (Enhanced DDEEC) which has also three-level of energy node in heterogeneous environment. EDDEEC proposed a probability function for CH selection. The super nodes and advanced nodes are more probable to be elected as head node, and after some time a situation occurs at which these nodes will have the same CH election probability as the normal nodes.

T. N. Qureshi et al. [13] introduced a protocol BEENISH (Balanced Energy Efficient Network Integrated Super Heterogeneous) in which an extra amount of energy level node known as ultra-super node is added. This protocol has four level of heterogeneity. Here advanced nodes, super nodes, ultra-super nodes have higher energy than normal nodes. We get that the nodes have more probability to become head node which have more residual energy, so the higher energy nodes will become CH more as compared to the lower energy nodes. A situation occurs in the network where higher energy nodes have same residual energy as normal nodes. Although, BEENISH continuously penalize the higher energy nodes in the selection of CH, so this is not optimal way for energy distribution. We introduce a new protocol TSA-BEENISH by modifying the probability approach and threshold formulae, with merging of TEEN. This protocol makes a balanced network and gives better stability period, throughput, and network lifetime.

III. RADIO DISSIPATION MODEL

We use Radio Energy Model which is taken from [15, 16]. In this model the transmitter dissipates total energy E_{TX} and the receiver dissipates total energy E_{RX} as shown in Fig.1. In wireless channel, the electromagnetic wave propagation

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can be modelled as falling off as a power law function of the distance between the transmitter and receiver. In order to achieve Signal-to-Noise Ratio (SNR) in transmitting an L-bit message over a distance d, Energy dissipation by radio model is given as:

$$E_{TX}(L,d) = \begin{cases} LE_{elec} + L\varepsilon_{fs}d^2 , if\ d < do \\ LE_{elec} + L\varepsilon_{mp}d^4 , if\ d \geq do \end{cases} \quad (1)$$

Where E_{elec} is energy used dissipated per bit to run transmitter (E_{TX}) or receiver (E_{RX}) circuit. ε_{fs} and ε_{mp} depend on the radio model used, and d is the distance between the sender and the receiver. Free space model (d^2 $power\ loss$) which consider direct line-of-sight and two-ray ground propagation is considered. if distance between transmitter and receiver Multi path fading (d^4 $power\ loss$) channel models is used when distance is more than threshold distance which consider two-ray ground propagation. d_o is threshold distance. By equating the two expressions at $d = d_o$, we have

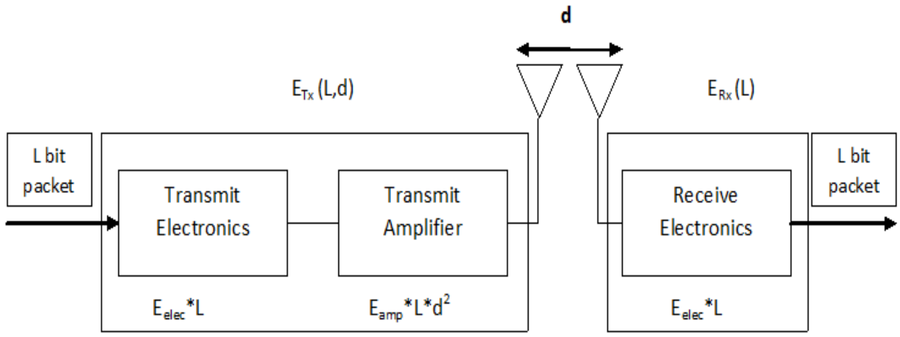

Fig.1. Radio Energy Dissipation Model

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (2)$$

For receiving the data energy dissipation of receiver is

$$E_{RX} = L.E_{elec} \quad (3)$$

IV. PROPOSED TSA-BEENISH ALGORITHM

In our proposed approach TSA-BEENISH, we improve the BEENISH protocol by effectively using BEENISH and TEEN protocol. We present here a very crucial protocol in heterogeneous wireless sensor networks, named as TSA-BEENISH (Threshold Sensitive Advanced Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol). TSA-BEENISH uses residual energy of the nodes and average energy of the network in the formation of cluster. TSA-BEENISH is a heterogeneous cluster based routing protocol with four level of heterogeneity. Four level of heterogeneity means there are the nodes having different types of energy levels in the network. We include normal, advanced, super node and ultra-super nodes in the network. Ultra-super nodes have highest energy level, super nodes have lower energy than ultra-super, advanced nodes have lower energy than super nodes, and normal nodes have lowest energy level.

A. Heterogeneous Network Model-

In this segment, N number of randomly deployed nodes over a field of $M \times M$ is assumed. TSA-BEENISH uses the concept of four level hierarchy model which has four types of nodes; normal, advance, super and ultra-super nodes

while in my proposed protocol. Heterogeneity may be of two, three, four or multi-level. E_o is the initial residual energy level of normal node whereas advance, super and ultra-super nodes are having a,b and u times more initial energy in comparison to normal nodes. m, m_o, m_1 ,are fractions of advanced, super and ultra-super respectively.
TSA-BEENISH protocol introduces the concept of five level heterogeneous WSNs as total energy described below [18].

$$E_{nrm} = N(1-m)E_o \quad (4)$$
$$E_{adv} = Nm(1-m_0)(1+a)E_o \quad (5)$$
$$E_{sup} = Nmm_o(1-m_1)(1+b)E_o \quad (6)$$
$$E_{ultra} = Nmm_o m_1(1+u) \quad (7)$$

$$E_{total} = E_{nrm} + E_{adv} + E_{sup} + E_{ultra}$$
$$= NE_o(1 + m\left(a + m_o(-a + b + m_1(u + m_2(d-u)))\right)) \quad (8)$$

Thus the total initial energy of the network is having $m\left(a + m_o(-a + b + m_1(u + m_2(d-u)))\right)$ times excess energy in comparison to WSNs of homogeneous nature.

B. Cluster Formation-

Each node S_i have probability to be elected as a cluster head with four types of nodes given by BEENISH [13] as:

$$P_i = \begin{cases} \dfrac{P_{opt}E_i(r)}{\{1 + m(\alpha + m_o(-a + b + m_1(-b+u)))\}\bar{E}(r)} & , s_i \ normal\ nodes \\ \dfrac{\{1+\alpha\}P_{opt}E_i(r)}{\{1 + m(\alpha + m_o(-a + b + m_1(-b+u)))\}\bar{E}(r)} & , s_i \ advanced\ nodes \\ \dfrac{\{1+b\}P_{opt}E_i(r)}{\{1 + m(\alpha + m_o(-a + b + m_1(-b+u)))\}\bar{E}(r)} & , s_i \ super\ nodes \\ \dfrac{\{1+u\}P_{opt}E_i(r)}{\{1 + m(\alpha + m_o(-a + b + m_1(-b+u)))\}\bar{E}(r)} & , s_i \ ultrasuper\ nodes \end{cases} \quad (9)$$

The above expression of Eq. 9 helps to find better network lifetime than all other two or three level of heterogeneous networks. But the main problem is that BEENISH continuously penalize just the advanced nodes, super nodes, and ultra-super nodes. So these advanced, super, and ultra-super nodes will always become a cluster head, then they will expire quickly.
As discussed in TEEN [20], Reactive Network Protocol: TEEN -In this section, we present a new network protocol called TEEN (Threshold sensitive Energy Efficient sensor Network protocol). It is targeted at reactive networks and is the first protocol developed for reactive networks, to our knowledge.
In this scheme, at every cluster change time, in addition to the attributes, the cluster-head broadcasts to its members,
Hard Threshold (HT): This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head.
Soft Threshold (ST): This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit.
The nodes sense their environment continuously. The first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends the sensed data. The sensed value is stored in an internal variable in the node, called the *sensed value (SV)*. The nodes will next transmit data in the current cluster period, only when both the following conditions are true:

1. The current value of the sense d attribute is greater than the hard threshold.
2. The current value of the sensed attribute differs from *SV* by an amount equal to or greater than the soft threshold.

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Whenever a node transmits data, *SV* is set equal to the current value of the sensed attribute.
Thus, the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions by eliminating all the transmissions which might have otherwise occurred when there is little or no change in the sensed attribute once the hard threshold.

So average energy of r[th] round in the network is to be calculated as follows:

$$\overline{E}(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R}\right) \quad (10)$$

Where "r" is the current round and "R" denotes total round of the whole network. "n" is the number of nodes in the network. "R" can be formulated as:

$$R = \frac{E_{total}}{E_{round}} \quad (11)$$

Some nodes may not die at last due to the factor "R" because H(r) may be too extent at the end.
E_{round} is the energy dissipated in a network during single round as given and calculated as:

$$E_{round} = L\left[2NE_{elec} + NE_{DA} + N\varepsilon_{fs}d_{toCH}^2 + k\varepsilon_{mp}d_{toBS}^4\right] \quad (12)$$

Where E_{elec} is energy used per bit for running circuit of transmitter and receiver. Free space (fs) model is used if distance is in less than threshold otherwise multi path (mp) model is used.
k= number of clusters,
E_{DA}=Data aggregation cost in CH
d_{toBS}= Average distance Between CH and BS
d_{toCH}= Average distance between cluster members and CH
Assuming all nodes are uniformly distributed over network so,d_{toBS} and d_{toCH} can be calculated as following

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}}, \qquad d_{toBS} = 0.765\frac{M}{2}$$

By finding the derivative of E_{round} with respect to zero, we get the k_{opt} optimum number of clusters as,

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{E_{fs}}{E_{mp}} \frac{M}{d_{toBS}^2}} \quad (13)$$

Our proposed probabilities for CH selection in TSA-BEENISH same as BEENISH protocol as equation (9)
Threshold can be calculated by expression in the following equation, and as supposed in [10].

$$T(s_i) = \begin{cases} \frac{P_i}{1-P_i\left(r \bmod \left(\frac{1}{P_i}\right)\right)} * \frac{E_i(r)}{\overline{E}(r) * K_{opt}} & if\ s_i \in G \\ 0 & otherwise \end{cases} \quad (14)$$

The node which is under set that belongs to G only they are eligible to be cluster head otherwise the nodes which already been selected as cluster head in a round gets out of the set of G. So in this way the threshold value selects the CH among the normal, advance, super and ultra-super nodes by using the value of P_i from the equation (5).

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At start of each round in TSA-BEENISH, cluster head transmits the following values:

i. *Report time*- Total time duration in which data is sent by node.

ii. *Attributes*- group of physical parameters.

iii. *Hard Threshold*- predefined threshold value of attributes beyond which node will send data to cluster head [19].

iv. *Soft Threshold*- minimum possible value of attributes which spark the node to switch on its transmitter and broadcast the data [19].

In fig. 2 flow chart of proposed algorithm which contains following step for cluster head selection and transmit data packets as follows:

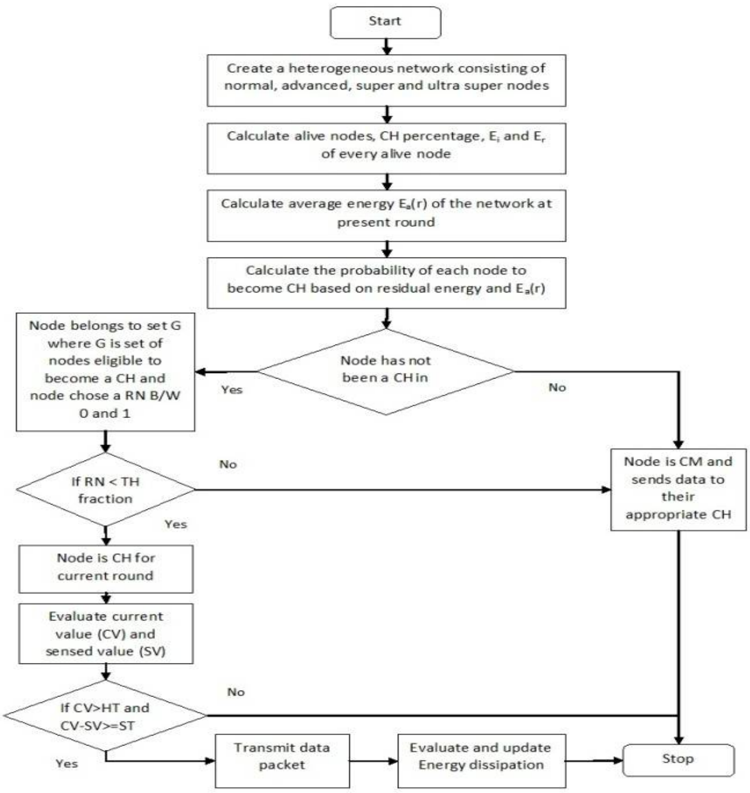

Fig. 2.Flow Chart of TSA-BEENISH Algorithm

V. SIMULATION AND RESULTS

In our experiments, we use MATLAB to create a network with 100 nodes deployed in 100m x 100m fields and a sink is in the middle of the network. We are deployed 50 normal nodes with initial energy E_o=0.5, 35 advanced nodes with 1.5 times extra initial energy as compared to normal nodes, 12 super nodes with 2.0 times extra initial energy as compared to normal nodes, and 3 ultra-super nodes with 2.5 times extra energy as compared to normal nodes (m=0.5, m_1=0.3, m_2=0.2, a=l.5, b=2.0, u=2.5). Our proposed protocol is suitable for multi-level of initial energy nodes in the network.
In fig.3, we compare our proposed protocol with BEENISH. For BEENISH and TSA-BEENISH, first node dies at 1434 and 1344 respectively. This is known as stability period of nodes. So TSA-BEENISH is 15% more stable than BEENISH. Tenth node dies at 1413 and 1702 respectively. In fig. 3 and fig.4 all nodes die at 6669 and 7520 respectively. This is known as lifetime of network. Lifetime of TSA-BEENISH have 13% more as compared to

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BEENISH. Fig.5 shows that the number of packets 286197 and 357334 are sent by BEENISH and TSA-BEENISH. This is known as throughput.

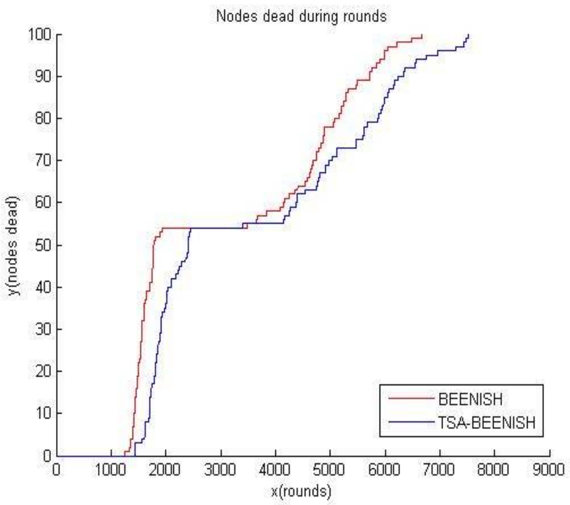

Fig. 3. Number of Dead nodes during network

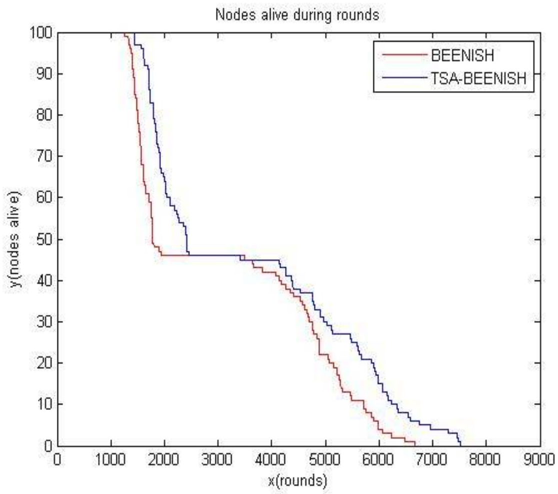

Fig. 4. Number of Alive nodes during network

Our proposed protocol sent 25% more packets as compared to BEENISH to the sink. In fig. 6 number of cluster head participated in the network for each round in BEENISH and TSA-BEENISH.

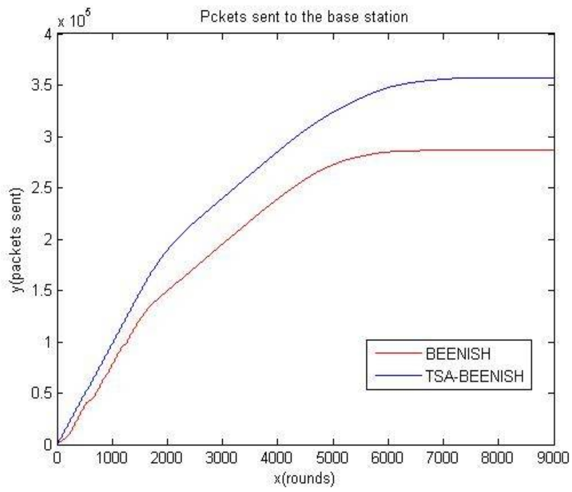

Fig. 5. Number of Packets send to the base station

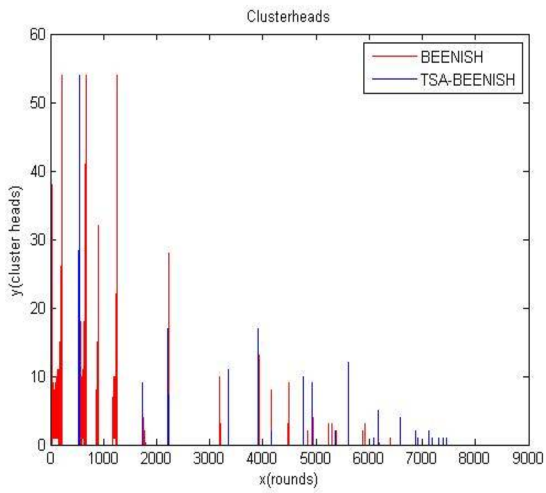

Fig. 6. Number of Cluster heads during network

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TABLE I.SIMULATION PARAMETERS

Parameters	Value
Network Field	(100,100) m^2
Number of nodes	100
Initial energy E_o	0.5J
Packet Size	4000 Bits
E_{elec}	50nJ/bit
ε_{fs}	10nJ/bit/ m^2
ε_{mp}	0.0013pJ/bit/ m^4
E_{DA}	5nJ/bit/signal
d_o	70m
P_{opt}	0.1
Hard Threshold (HT)	100°C
Soft Threshold (ST)	2°C
Number of rounds	9000

VI. CONCLUSION

TSA-BEENISH is a reactive four level heterogeneous clustered routing protocols which combines the best feature of BEENISH and TEEN protocol, uses the hard threshold and soft threshold concept of TEEN protocol to reduce the communication cost. As we compared our protocol TSA-BEENISH to BEENISH, by giving a different probability approach and appropriate threshold formulae, the proposed protocol gives much better result as compared to the existing protocol. After experiments on various parameters we find that TSA-BEENISH gives better performance than BEENISH.

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