ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

EBEENISH- Enhanced Balanced Energy Efficient Network Integrated Super Heterogeneous protocol for Wireless Sensor Networks

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Manuscript Info

Manuscript History:

Received: 18 August 2015
Final Accepted: 22 September 2015
Published Online: October 2015

Key words:

CH, BS, heterogeneity, efficiency and WSNs

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Abstract

In the past few years, wireless sensor networks have been the area of interest for many researchers. The foremost defy in the field of WSNs is energy efficiency. Various clustering protocols had been designed to increase the lifetime of sensor networks and to make the network much stable. In this paper we have designed a novel routing protocol for heterogeneous sensor networks which is E-BEENISH (Enhanced Balanced Energy Efficient Network Integrated Super Heterogeneous) protocol. In this protocol, five different levels of sensor nodes have been used with varying energy levels. The selection of cluster heads is based on the residual energy levels of the sensor nodes and average energy of the sensor network. Simulation results shows that this protocols givers better results as compared to DEEC (Distributed Energy Efficient Clustering), DDEEC (Developed Distributed Energy Efficient Clustering), EDEEC (Enhanced Distributed Energy Efficient Clustering) and BEENISH (Balanced Energy Efficient Network Integrated Super Heterogeneous) protocols, in terms of efficiency, network lifetime and stability.

INTRODUCTION

Wireless sensor networks consists of large number of tiny devices called sensor nodes. These nodes are used to sense the data from the sensor field and send it to the base station. These nodes are very small in size and have limited power. Due to limited battery lifetime, the sensor nodes expire soon and cannot participate in further processing. Therefore, the lifetime of the wireless network became the most important point for consideration in WSNs.

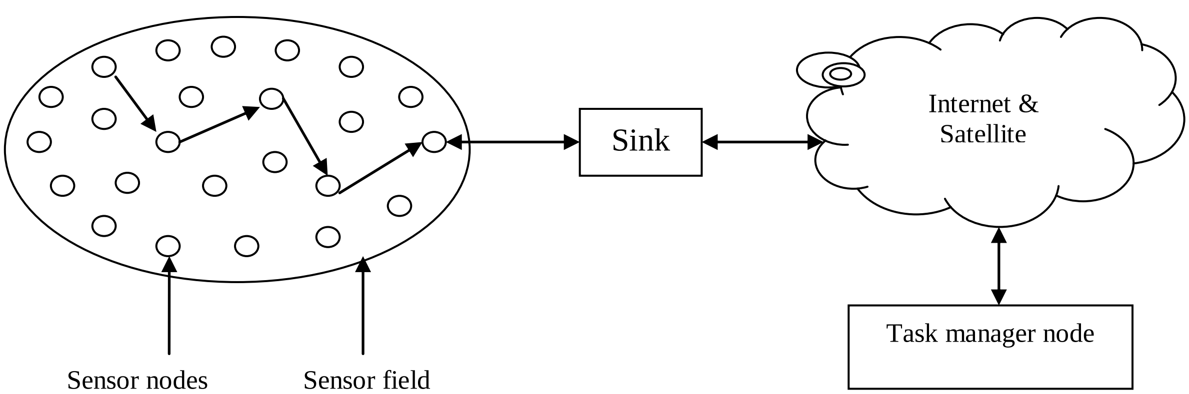

Figure 1: Architecture of WSN [1]

Routing protocols plays the most important role for improving the lifetime of the sensor network. The energy efficiency of sensor network is improved by clustering [3]. In clustering, the whole network is divided into small groups known as clusters. Each cluster is comprised of cluster head and member nodes. The cluster head (CH) is selected on the basis of energy level of that particular node. In this technique, the member nodes sense the data from the sensor field and transmit it to the CH. On receiving the data from member nodes, the CH performs data aggregation on the received data and transmits the information to the BS. The data aggregation process reduces the energy consumption of the nodes and as a result increases the lifetime of the sensor nodes.

Clustering can be performed on two types of sensor networks: homogeneous and heterogeneous networks. In homogeneous sensor networks [2], all the sensor nodes have same energy levels. Some of the examples of routing protocols designed for homogeneous networks are LEACH [4] (Low Energy Adaptive Clustering Hierarchical), PEGASIS [9] (Power Efficient Gathering in Sensor Information System), HEED (Hybrid Energy Efficient Distributed clustering). But these protocols perform poor in case of heterogeneous networks. In heterogeneous sensor networks [11], all the sensor nodes have different levels of energy which results in maximizing the lifetime of network. Some examples of routing protocols for heterogeneous sensor networks are DEEC [8] (Distributed Energy Efficient Clustering), EDDEEC [6] (Enhanced Developed Distributed Energy Efficient Clustering), EDEEC [12] (Enhanced Distributed Energy Efficient Clustering), BEENISH [7] (Balanced Energy Efficient Network Integrated Super Heterogeneous protocol).

1. RADIO DISSIPATION MODEL

The radio dissipation model illustrates that M bit of message is transmitted over distance d [4] as shown in figure 2:

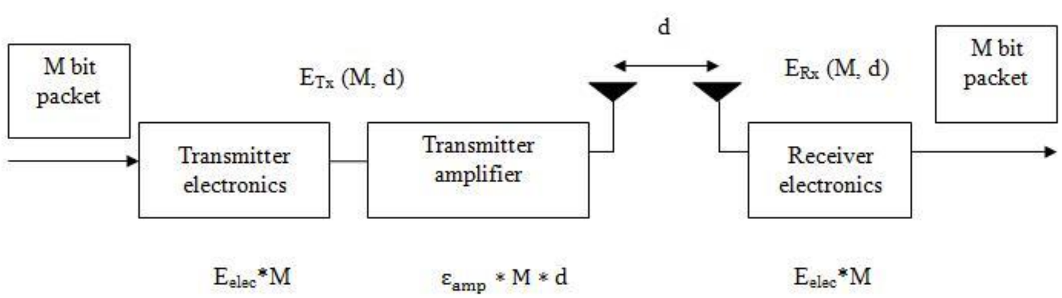

Figure 2: Radio dissipation model [4]

In our analysis, we used the identical model as used in [7]. The amount of energy used for transmission of information is given as follows:

$$E_{Tx}(M,d) = \begin{cases} ME_{elec} + M\varepsilon_{fs}d^2, d < d_o \\ ME_{elec} + M\varepsilon_{mp}d^4, d \geq d_o \end{cases} \quad (1)$$

Where E_{elec} is the electronics energy used for transmission or reception of information. d_o is the cross over distance and is given as:

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

When the distance 'd' is less than cross over distance 'd_o' then the free space model 'ε_{fs}' is used. When the distance 'd' is greater than cross over distance 'd_o' then multi path model 'ε_{mp}' is used. The amount of energy used by receiver electronics is given as:

$$E_{Rx} = E_{elec}\, M \quad (3)$$

Therefore, the total energy dissipated in a round is given as:

$$E_{round} = M\,(2N\,E_{elec} + NE_{DA} + k\varepsilon_{mp}\,d^4_{to\ BS} + N\varepsilon_{fs}d^2_{to\ CH}) \quad (4)$$

Where k is the number of clusters; E_{DA} is the energy used for data aggregation by cluster head; $d_{to\ BS}$ is the average distance between the base station and cluster heads; and $d_{to\ CH}$ is the average distance between cluster head and member nodes [8].
Now, $d_{to\ BS}$ and $d_{to\ CH}$ can be calculated as:

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}} \tag{5}$$

$$d_{toBS} = 0.765\frac{M}{2} \tag{6}$$

By obtaining the derivative value of E_{round} with respect to k to zero, we get the optimal number of clusters, which are given as:

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi r}}\frac{\varepsilon_{fs}}{\varepsilon_{mp}}\frac{M}{d_{toBS}^2} \tag{7}$$

2. EBEENISH PROTOCOL

In this section, we present details of our EBEENISH protocol. This protocol executes the same notion for formation of clusters and selection of cluster heads, which is based on the residual energy of sensor nodes and average energy of sensor network. In our protocol, we used sensor nodes having five different energy levels namely: normal, advanced, super, ultra-super and ultra-advanced super nodes.
In EBEENISH protocol, the average energy of r^{th} round is given as [8]:

$$E_a = \frac{1}{N}E_{total}\left(1 - \frac{r}{r_{max}}\right) \tag{8}$$

r_{max} is the total number of rounds throughout the lifetime of the network, i.e. from the starting of the network to the time till all the nodes inside the network dies out. It is given as:

$$r_{max} = \frac{E_{total}}{E_{round}} \tag{9}$$

In the starting of each round, the sensor nodes decides whether to become the CH for that particular round or not, by comparing its energy level with the threshold value, which is given as follows:

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i(r mod \frac{1}{p_i})}, if\ s_i \in G \\ 0 \qquad otherwise \end{cases} \tag{10}$$

where G is the set of sensor nodes which are appropriate to become CH. In EBEENISH protocol, there are five levels of sensor nodes namely: normal, advanced, super, ultra-super and ultra-advanced nodes and all these sensor nodes have different probability functions which are given as follows:

(i) When $E \le E_0$ then the probability is given as follows:

$$p(i) = \frac{p * E(i)}{E_a * (m * \left(\left((b + c + (-c + d) * m_2\right) * m_1 + b - a\right) * m_0 + a\right) + 1)}$$

(ii) When $E \le E_0 * (1+a)$ then the probability is given as follows:

$$p(i) = \frac{p * E(i) * (1 + a)}{E_a * (m * \left(\left((b + c + (-c + d) * m_2\right) * m_1 + b - a\right) * m_0 + a\right) + 1)}$$

(iii) When $E \le E_0 *(1+b)$ then the probability is given as follows:

$$p(i) = \frac{p * E(i) * (1 + b)}{E_a * (m * \left(\left((b + c + (-c + d) * m_2\right) * m_1 + b - a\right) * m_0 + a\right) + 1)}$$

(iv) When $E \le E_0 * (1+c)$ then the probability is given as follows:

$$p(i) = \frac{p * E(i) * (1+c)}{E_a * (m * \left(((b + c + (-c + d) * m_2) * m_1 + b - a) * m_0 + a \right) + 1)}$$

(v) When $E \le E_0 * (1+d)$ then the probability is given as follows:

$$p(i) = \frac{p * E(i) * (1+d)}{E_a * (m * \left(((b + c + (-c + d) * m_2) * m_1 + b - a) * m_0 + a \right) + 1)}$$

. The probability functions for these nodes are given as follows:

$$p_i = \begin{cases} \frac{p*E(i)}{E_a*(m*\left(((b+c+(-c+d)*m_2)*m_1+b-a)*m_0+a\right)+1)} \\ \frac{p*E(i)*(1+a)}{E_a*(m*\left(((b+c+(-c+d)*m_2)*m_1+b-a)*m_0+a\right)+1)} \\ \frac{p*E(i)*(1+b)}{E_a*(m*\left(((b+c+(-c+d)*m_2)*m_1+b-a)*m_0+a\right)+1)} \\ \frac{p*E(i)*(1+c)}{E_a*(m*\left(((b+c+(-c+d)*m_2)*m_1+b-a)*m_0+a\right)+1)} \\ \frac{p*E(i)*(1+d)}{E_a*(m*\left(((b+c+(-c+d)*m_2)*m_1+b-a)*m_0+a\right)+1)} \end{cases} \quad (11)$$

These are the probabilities for normal, advanced, super, ultra-super and ultra-advanced nodes respectively. The values of equation (11) are putted in equation (10) and according to the result CH selection is performed. After the selection of CH, the cross over distance is calculated using the formula:

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (12)$$

Now the distance between the CH to member nodes as well as the distance between CH and the BS is calculated using the equations (5) and (6) and the obtained value is compared with the value obtained in equation (12). If the value of distance is greater than the cross over distance, then multi-path model is used. And if the distance is less than or equal to cross over distance then the free space model is used.

$$E = E - \left(E_{tx} * (5000) + \varepsilon_{mp} * 5000 * d^4\right), for\ d > d_0 \quad (13)$$

$$E = E - (E_{tx} * (5000) + \varepsilon_{fs} * 5000 * d^2), for\ d \le d_0 \quad (14)$$

The nodes are assigned different amount of energies according to the five levels of energy.

1. For normal nodes:
S(i).E=E_0;
S(i).ENERGY= 0;

2. For advanced nodes:
S(i).E= E_0*(1+a);
S(i).ENERGY= 0.5;

3. For super nodes:
S(i).E= E_0*(1+b);
S(i).ENERGY= 1;

4. For ultra-super nodes:
S(i).E= E_0*(1+c);
S(i).ENERGY= 1.5;

5. For ultra-advanced nodes:
S(i).E= E_0*(1+d);
S(i).ENERGY= 2;

Based on these energy levels, the sensors are divided into five groups each having different energy. The initialization of the algorithm, there are no cluster heads. Based on the energy levels the CH selection is performed. On completion of each round the remaining energy level of each sensor nodes is checked and then depending upon the residual value new CHs are formed. The nodes having higher residual energy value have greater possibility to become CHs. This process continues till all the sensor nodes are dead. A node is considered dead if its energy level goes below the desired limit and it cannot participate in further transmission as well as sensing process.

3. SIMULATIONS AND RESULTS

In this section we have presented the simulation of EBEENISH protocol using MATLAB. The parameters used for evaluation of various clustering protocols in heterogeneous WSNs are described in Table 1.

Table 1: Parameters used in simulation

Parameter	Description	Value
$X_m \times Y_m$	Dimensions of field	100m × 100m
N	Number of nodes	100
R_{max}	Maximum number of rounds	20000
P	Probability of node to become CH	0.1
E_0	Initial energy of each node	0.5 J
E_{elec}	Electronics energy	10^{-9} J
EDA	Data aggregation energy	10^{-9} J
ε_{fs}	Energy dissipation for free space	10^{-12} J
ε_{mp}	Energy dissipation for multipath	10^{-16} J
M	Packet size	50

First of all we considered a WSN in which 100 sensor nodes are deployed as shown in Figure 3.

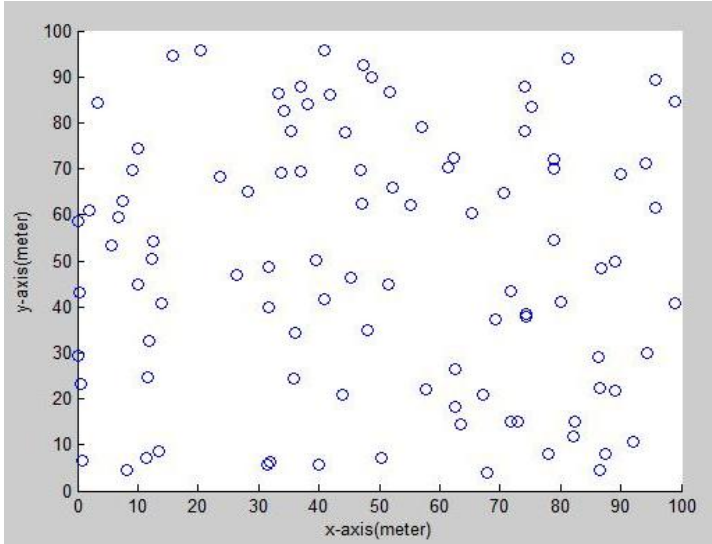

Figure 3: Random deployment of sensor nodes

We consider an area of 100m×100m. In this area, N=100 sensor nodes are randomly deployed with five levels of energy as shown in Figure 4. Different symbols indicate different levels of sensor nodes. We assumed that all the sensor nodes are either fixed or micro-mobile and ignored all the energy losses which are caused due to collision of various signals and interference caused due to signals of different sensor nodes as these nodes are randomly distributed inside the sensor field. We also assumed that the position of BS is at the centre of the wireless senor field. The protocols which we used for comparison with EBEENISH comprise DEEC, DDEEC, EDEEC and BEENISH. We take the parameters m=0.1, m_0= 0.2, m_1= 0.3 and m_2= 0.4, a= 3, b= 1.5, c= 4.5 and d= 6.

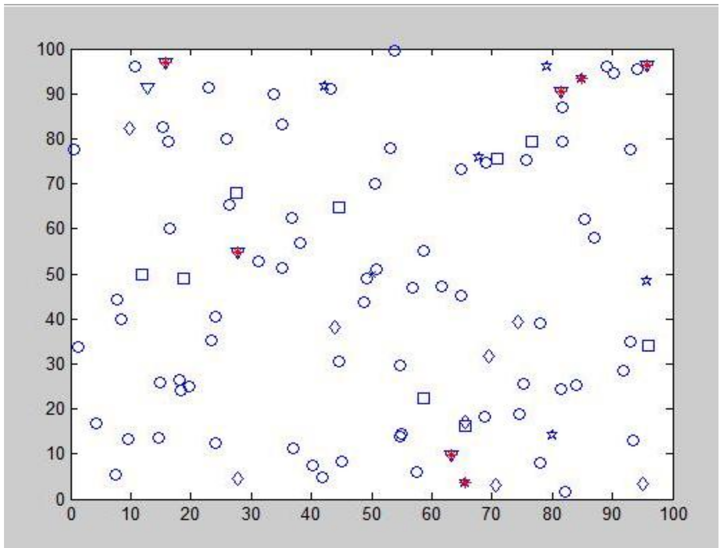

Figure 4: Five levels of energy in sensor nodes

In figure 4 sensor nodes with different levels of energy are shown. The energy level is divided into five groups namely: normal, advanced, super, ultra-super and ultra-advanced nodes respectively. The sensor nodes with highest amount of energy have more chances of being selected as CH as compared to low energy sensor nodes. The sensor nodes participate in sensing the information and transmitting it to the CHs. The CH performs data aggregation and forwards the data to the BS. In this way the process is continued till the time all the sensor nodes are dead in wireless sensor field.

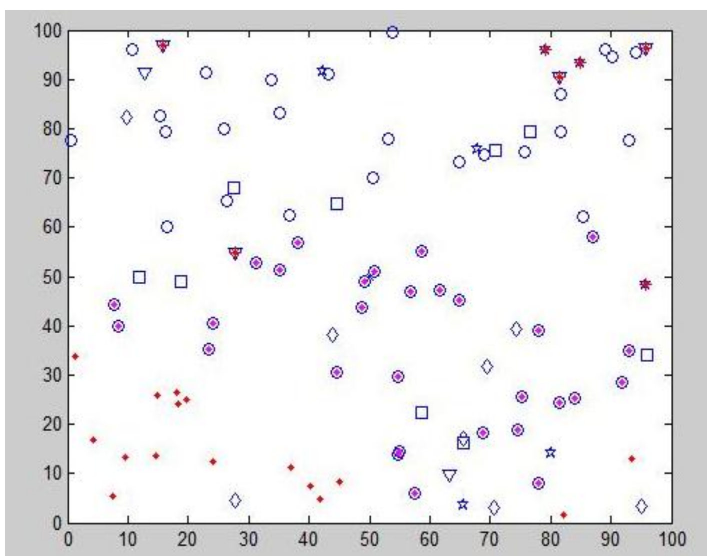

Figure 5: Some alive and some dead nodes

Figure 5 shows some sensor nodes which have been participated in the sensing process and some sensor nodes are in ideal mode whereas some nodes are dead which cannot participate in further sensing process. The nodes which are dead are represented by red colour. The nodes which have been participated in sensing and transmission are represented by pink colour whereas the ideal nodes are represented by symbols. Figure 6 shows all sensor nodes are dead. And no further sensing can be performed after this.

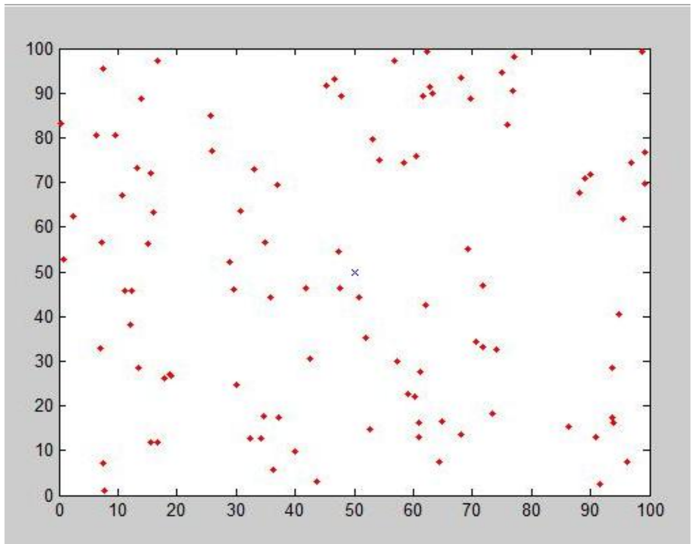

Figure 6: All sensor nodes dead

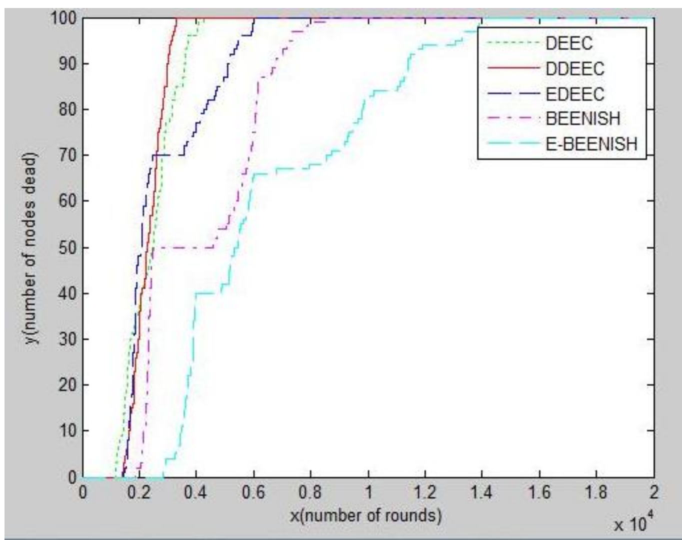

Figure 7: Number of nodes dead during network lifetime

Figure 7 shows the experimental results of EBEENISH protocol which demonstrate the number of sensor nodes dead during network lifetime. Number of rounds is demonstrated along x-axis and y-axis represents the number of nodes dead during network lifetime. By observing the nodes with respect to number of rounds it is observed that first node for DEEC protocol dies at 1157 round. First node for DDEEC protocol dies at 1358 round. First nodes for EDEEC protocol dies out at 1471 round. First node for BEENISH protocol dies out at 1857 round and first node for EBEENISH protocol dies at 2829 round. This means EBEENISH protocol can perform approximately 2800 rounds without any node being died out.

Figure 8 shows the number of nodes alive in number of rounds.

Figure 9 shows number of data packets sent to the BS. In case of EBEENISH protocol, the number of data packets sent to the BS is approximately 6.5×10^5 which is far better than performance of BEENISH protocol. Therefore, it is clear from this figure that the EBEENISH protocol gives better performance than other routing protocols in terms of energy efficiency, stability and network lifetime.

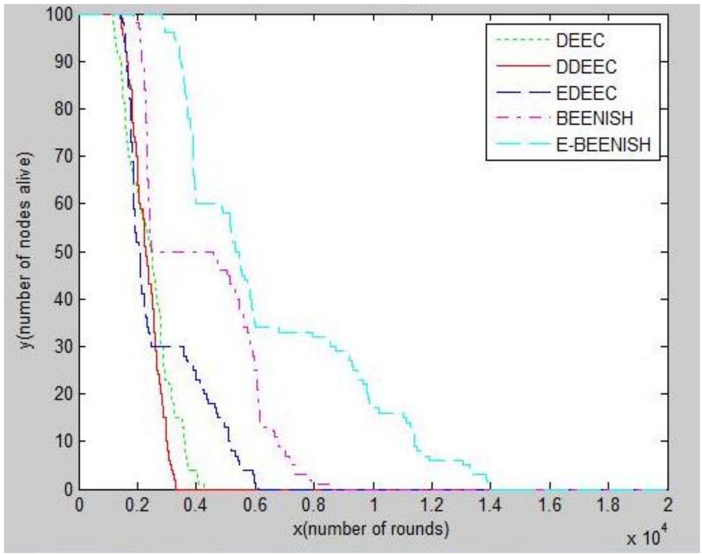

Figure 8: Number of alive nodes during network lifetime

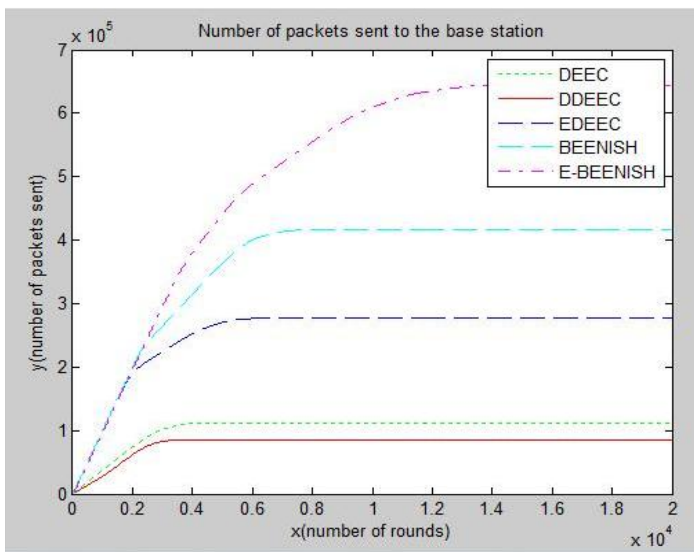

Figure 9: Packets sent to BS

4. CONCLUSION

In this paper energy aware enhanced balanced energy efficient network integrated super heterogeneous protocol (EBEENISH) is presented. The protocol is used to maximize the lifetime of the network. It uses the concept of five different energy levels. Simulation results shows that EBEENISH protocol gives better performance as compared to other routing protocols such as DEEC, DDEEC, EDEEC and BEENISH in terms of energy efficiency, stability and network lifetime.

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BIBILIOGRAPHY

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