Proceedings of the 12th INDIACom; INDIACom-2018; IEEE Conference ID: 42835
2018 5th International Conference on "Computing for Sustainable Global Development", 14th - 16th March, 2018
Bharati Vidyapeeth's Institute of Computer Applications and Management (BVICAM), New Delhi (INDIA)

Energy Efficient Distributed Clustering Algorithm for Improving Lifetime of WSNs

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Abstract—**In wireless sensor networks, there has been so many sensor nodes and all are operated with limited power supplied by the battery source. The nodes in the network use energy to sense and process the information gathered from its surroundings and communicate it to the central system. In order to optimize the energy consumption of sensor nodes, many routing and clustering protocols have been given, so as to get large energy efficiency in heterogeneous network scenario. But the limited lifetime of network is still widely regarded as a fundamental bottleneck of performance. Clustering plays a significant and efficient role to control the energy consumed by sensor nodes,as the routing and relaying of data is done by the cluster heads and hence prolongs the lifetime of networks. The introduction of network heterogeneityfurther improves nodes lifetime and network reliability. In this paper, we have proposed distributed and energy efficient clustering protocols that follow the concepts of Distributed Energy Efficient Clustering protocol.**

Keywords—Energy Efficient, Heterogeneity, Clustering Algorithm, Network Lifetime.

I. INTRODUCTION

Recent developments in the areas of MEMS (Micro Electro Mechanical Systems), wireless communication and low power designs have enabled the small sized battery operated sensor nodes. A sensor node can be an electro-mechanical device which measures some physical quantity and converts it into the signal which is used by the instrument. Sensor nodes are not only used in science and engineering, but also find applications in areas such as the military, home automation, field monitoring, medical data collection or surveillance, and earthquake monitoring are the examples of sensor monitoring. Energy efficiency remains one of the objectives mostly in all researches related to WSNs in these days since the sensor nodes have limited energy, and the replacement of batteries often is not very practical. Another feature of these networks is that these are mostly unattended to, and can be self-configuring or self-organizing. In terms of node placement, a typical WSNscan comprise of very large number of sensors that can be densely placed over a large geographical area.

A. *Clustering Techniques*

A large number of energy-efficient routing protocols are developed using the idea of clusters. In sensor networks, clustering is the division of sensor nodes in groups. A cluster head present in every cluster, it is either selectedmanually or made by its neighbour nodes in the group. The cluster head collects the sensed data by the sensor nodes and transfer to the base station(BS). The clustering technique in a network can also be used to perform data aggregation. The sensor nodes transmit such sensed data, using a radio transmitter antenna, to an access point (sink) orBS, either directly or using gateway. Gateway helps to pass the data by acting himself as amediator between the sink and cluster head.

B. *Types of Clustering Techniques*

Clustering technique is mainly used in the WSNs to improve the lifetime of network and lowering the energy consumption by providing power efficiency, scalability, and security. In the early days sensor nodes are mainly used as the homogeneous nodes in which all the nodes has the same processing capacity, energy, and functionality, but to increase the network lifetime researchers has been developed a method by integrating the heterogeneity in nodes of WSNs such as to provide different energy level of distribution in some nodes. Clustering algorithm should be energy efficient.

II. HETEROGENEOUS WSNS MODEL

In heterogeneous WSNs(H-WSNs), there are different kinds of sensor nodes having two, or more types of the sensor nodes on the basis of their level of energy and called as two tier or multi-tier H-WSNs respectively.

In our proposed protocol we consider five-level and six-level of aheterogeneous node in the WSNs. According to the heterogeneity, the sensor nodes are classified as normal node(NN), advanced node(AN), super node(SN), ultra-super node(USN), hyper node(HN), and ultra-hypernode(UHN).

Now, assume that the NNs energy is E_o.

ANs having energy with the fraction *m* and *time* more energy as compared with the normal nodes, i.e., E_o+ E_oa= E_o(1+a)

SNs having the fraction m_o and b times greater energy as compared with the NNs, i.e., E_o+ E_ob =E_o (1+b).

USNs having the fraction m_1 and c times more energy as compared with the NNs, i.e., E_o+ E_oc =E_o(1+c).

HNs having the fraction m_2 and d times more energy as compared with the normal ones,

i.e., E_o+ E_od =E_o(1+d).

UHNs having the fraction m_3 and e times more energy as compared with the normal ones, i.e., E_o+ E_oe =E_o(1+e).

Now we consider a network having N nodes then the number of NNs, ANs, SNs, USNs, HNs and UHNs are

Number of NNs are N(1-*m*).

Number of ANs are N*m*(1-m_o).

Number of SNs are Nmm_o(1-m_1).

Number of USNs are Nmm_om_1(1-m_2).

Number of HNs are N$mm_om_1m_2$(1-m_3).

Number of UHNs are N$mm_om_1m_2m_3$.

Then the initial energy of nodes are:

NN energy is

$$E_{normal}=NE_o(1-m) \quad (1)$$

AN energy is

$$E_{advanced}=Nm(1-m_o)E_o(1+a) \quad (2)$$

SN energy is

$$E_{super}=Nmm_o(1-m_1)E_o(1+b) \quad (3)$$

USN energy is

$$E_{ultrasuper}=Nmm_om_1(1-m_2)E_o(1+c) \quad (4)$$

HN energy is

$$E_{hyper}=Nmm_om_1m_2(1-m_3)E_o(1+d) \quad (5)$$

UHN energy is

$$E_{ultrahyper}=Nmm_om_1m_2m_3E_o(1+e) \quad (6)$$

A. Energy consumption model

The energy consumed by a sensor node relies on its internal parts used for special purposes like information processing module, information sensing module (refer to Fig. 1).

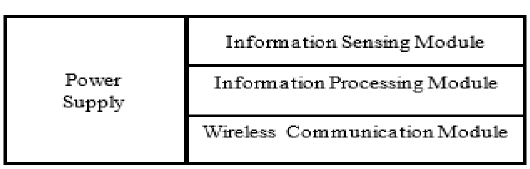

Fig. 1. Basic architecture of a node

$E_S$is the information sensing module energy consumption, $E_P$is the information processing module energy consumption, and $E_W$is the wireless communication module energy consumption and node total energy denoted as E_T.

So, total energy used by node "E_T" is in equation as

$$E_T= E_S+ E_P+ E_W \quad (7)$$

Now, energy used in each module is calculated separately as follows

1) Case 1

When a sensor node is placed in WSN it first sense the environment by the sensing module and the sensing module carry out three tasks first is signal sampling, second is A/D conversion of the signal and the third is the modulation of signal.By using the switching energy model [11], E_S can be written as:

$$E_S= E_{00}+E_{10} + E_{01} + E_{11} \quad (8)$$

In the above equation the symbol E_{10}denotes the quantity of energy used when switching from the alive conditionto dead condition, and the symbol E_{01}denotes the energy used when switching from dead to alive condition, E_{11}denotes energy used in the sensing operation and the E_{00}=0 because no energy is used when the sensor is ideal.

Now, to calculate the E_{11} the current I of a sensor getmultiplied by the voltage Vand the time interval used in sensing operation T_s, then it yields E_{11}, i.e.,

$$E_{11} = VIT_s.$$

2) Case 2

Total power consumed by the processing module is given as

$$E_P= E_P^{Stat}+E_P^{Xion} \quad (9)$$

Where E_P^{Stat} = state or condition energy consumptionandE_P^{Xion}=state or condition transition energy consumption

The formula [9] can be rewritten in the more pictorialrepresentation as:

$$E_P= \sum_{i=1}^{m} P_p^{Stat}(i) * T_p^{Stat}(i) + \sum_{j=1}^{m} X_p^{Xion}(j) * E_p^{Xion}(j) \quad (10)$$

Where,

i= 1, 2,…., m is the condition state of processing unit and

j = 1, 2, ….., nis the state of transition unit

P_p^{Stat} =power consumption cost

T_p^{Stat} =time interval

X_p^{Xion} =frequency of the state transition

E_p^{Xion} =energy used in one state transition

1) Case 3

In this case the power consumed by wireless communication module as shown in fig. 1 is calculated by using the radio model [4] shown in fig. 2.

Now,$E_W = E_{Tx}$ or $E_W = E_{Rx}$

Where,

E_P=Energy used by wireless communication module

E_{Tx} =Energy used in transmission of signal E_{Rx}= Energy used in receiving of signal

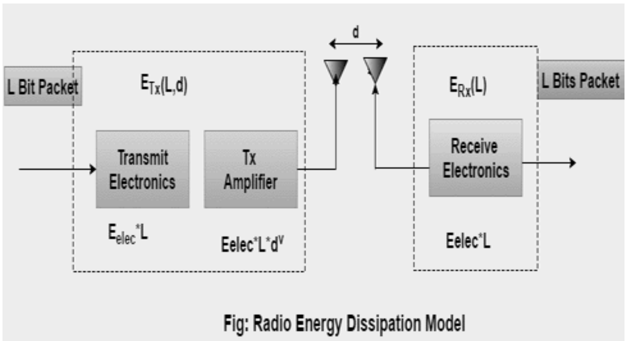

Fig. 2. Radio model

If the message of l bitsare being send/received by the distance d, thenthe consumed energycan be given as [8]:

$$E_W = E_{Tx/Rx}(l,d) = \begin{cases} lE_{elec} + l\epsilon_{fs}d^2 & , \quad d < d_0 \\ lE_{elec} + l\epsilon_{mp}d^4 & , \quad d \geq d_0 \end{cases} \quad (11)$$

Where, E_{elec} denotes the energy consumed at node to run Tx/Rx circuit per bit

ϵ_{fs}=radio amplifiers for the free space

ϵ_{mp}= radio amplifiers for the multi-path

d = distance between the Tx and the Rx

And d_0=reference distance

B. Heterogeneous protocol

The heterogeneous protocol implementation is based uponthe chances for CHs selection by considering the starting energy, residual energy of sensor nodes and also on the average value of energy consumed by the network.

The r^{th} round average energy is calculated as [5]:

$$\bar{E}(r) = \frac{1}{N} E_{total}\left(1 - \frac{r}{R}\right) (12)$$

Where, Ris the total rounds of network lifetime[8] and can be calculated as

$$R = \frac{E_{total}}{E_{round}} \quad (13)$$

Where, E_{round} is the energy consumed in the network forone round is given as,

$$E_{round} = l(2NE_{elec} + NE_{DA} + K\epsilon_{mp} d_{to\ BS}^4 + N\epsilon_{fs} d_{to\ CH}^2) \quad (14)$$

Where,

K= number of formed clusters in network

E_{DA}= energy used in data gathering by the cluster head

$d_{to\ BS}$ = average distance between BS and CH

$d_{to\ CH}$ = average distance between CH and CM

Now to calculate the value of $d_{to\ BS}$ and [10] $d_{to\ CH}$ is given as

$d_{to\ BS} = 0.765\frac{M}{\sqrt{2}}$ and

$$d_{to\ CH} = \frac{M}{\sqrt{2\pi K}} (15)$$

Now to find the best suited number of cluster in a network, done by differentiating E_{round} with respect to k [10] is given as

$$K_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}} \frac{M}{d_{to\ BS}^2} \quad (16)$$

Nodes calculate the threshold value to becomes cluster head or not and threshold probability is given as

$$Th(S_i) = \begin{cases} \frac{p_i}{1 - p_i\left(mod\left(r, \frac{1}{p_i}\right)\right)} & whenever S_i \epsilon G \\ null & else \end{cases} \quad (17)$$

Where,

G =Group of sensor which can become the CHs for round r and p is the required probability of Cluster head.

Now, calculate the total energy of the four tier network from eq. (1), (2), (3) and eq. (4) is

$E_{total} = E_{normal} + E_{advanced} + E_{super} + E_{ultrasuper}$ (18)

Then,

$E_{total} = NE_o(1-m) + Nm(1-m_o)*E_o(1+a) + Nmm_o*(1-m_1)*E_o(1+b) + Nmm_om_1*E_o(1+c)$

$E_{total} = NE_o[1-m+m+ma-m_om-m_oma+m_om+m_omb-m_omm_1-m_om_1mb+m_omm_1+m_omm_1c]$

$E_{total} = NE_o[1+ma-m_oma+m_omb-m_om_1mb+m_omm_1c]$

$$E_{total} = NE_o[1+m(a+m_o(-a+b+m_o(-b+c)))] \quad (19)$$

The corresponding probability of the four types of sensor nodes, from [9] BENNISH protocol is given as follows:

$$P_i = \begin{cases} \frac{P_{opt}E_i(r)}{\left(1+m\left(a+m_0(-a+b+m_1(-b+c))\right)\right)*\bar{E}(r)} & whenever\ S_i\ is\ NS \\ \frac{P_{opt}(1+a)E_i(r)}{\left(1+m*\left(a+m_0*(-a+b+m_1*(-b+c))\right)\right)*\bar{E}(r)} & whenever\ S_i\ is\ AN \\ \frac{P_{opt}(1+b)E_i(r)}{\left(1+m*\left(a+m_0*(-a+b+m_1*(-b+c))\right)\right)*\bar{E}(r)} & whenever\ S_i\ is\ SN \\ \frac{P_{opt}(1+c)E_i(r)}{\left(1+m*\left(a+m_0*(-a+b+m_1*(-b+c))\right)\right)*\bar{E}(r)} & whenever\ S_i\ is\ USN \end{cases} \quad (20)$$

Given the above set of equations primarily illustrates the difference between the energy level of NNs, ANs, SNs, and USNs by defining the probabilities of their CH selection. Similarly, we can now calculate the probabilities of five level of energy distribution as to calculate by adding all the node's energy as the energy ofNNS, ANs, SNs, USNs and HNs is

$E_{total} = E_{normal} + E_{advanced} + E_{super} + E_{ultrasuper} + E_{hyper}$ (21)

$E_{total} = NE_o(1-m) + Nm(1-m_o)\ E_0(1+a) + Nmmo(1-m_1)E_o(1+b) + Nmmom1(1-m_2)E_o(1+c) + Nmmom_1m_2E_o(1+d)$ (22)

By solving the equation 22, we get

$E_{total=}NE_o[1+ma-m_oma_+m_omb-m_om_1mb+m_omm_1c-m_omm_1m_2c+m_omm_1m_2d]$

$E_{total=}NE_o[1+ma-m_oma_+m_omb-m_om_1mb+m_omm_1c-m_omm_1m_2c+m_omm_1m_2d]$

$E_{total=}NE_o[1+m(a_+m_o(-a+b+m_1(-b+c+m_2(-c+d))))]$

$$P_i = \begin{cases} \frac{P_{opt} * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*(-c+d)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is the NN} \\ \frac{P_{opt}\ (1+a)*E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*(-c+d)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is the AN} \\ \frac{P_{opt}\ (1+b)*E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*(-c+d)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is the SN} \\ \frac{P_{opt}\ (1+c)*E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*(-c+d)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is the USN} \\ \frac{P_{opt}\ (1+d)*E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*(-c+d)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is the HN} \end{cases}$$

(21)

Similarly, we can now calculate the probabilities of five level of energy distribution as to calculate by adding all the node's energy as the energy ofNNs, AN, SNs, USNs HN and the UHN is

$E_{total}=E_{normal}+E_{advanced}+E_{super}+E_{ultrasuper}+E_{hyper}+E_{ultrahyper}$

$E_{total}=Neo[(1-m)+Nm(1-m_o)E_o(1+a)+Nmm_o(1-m_1)E_o(1+b)+Nmm_om_1(1-m_2)E_o(1+c)+$

$Nmm_om_1m_2E_o(1+d)(1-m_3)+NE_o(1+e)(Nmm_om_1m_2m_3)]$ (22)

By solving the equation (22), we get

$E_{total}=NE_o[1+m(a_+m_o(-a+b+m_1(-b+c+m_2(-c+d+m_3(-d+e)))))]$

$$P_i = \begin{cases} \frac{P_{opt} * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*\left(-c+d+m_3*(-d+e)\right)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is NN} \\ \frac{P_{opt}(1+a) * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*\left(-c+d+m_3*(-d+e)\right)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is AN} \\ \frac{P_{opt}(1+b) * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*\left(-c+d+m_3*(-d+e)\right)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is SN} \\ \frac{P_{opt}(1+a) * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*\left(-c+d+m_3*(-d+e)\right)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is USN} \\ \frac{P_{opt}(1+a) * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*\left(-c+d+m_3*(-d+e)\right)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is HN} \\ \frac{P_{opt}(1+c) * E_i(r)}{\left(1+m*\left(a+m_0*\left(-a+b+m_1*\left(-b+c+m_2*\left(-c+d+m_3*(-d+e)\right)\right)\right)\right)\right)*\bar{E}(r)} & \text{whenever } S_i \text{ is the HN} \end{cases}$$

(23)

III. SIMULATION PARAMETER USED

TABLE I. SIMULATION PARAMETERS

Parameters	Value
Message Size	4000 bits
E_0 (Initial energy)	0.5 J
ϵ_{fs}	10 nJ/bit/m^2
E_{elec}	50 nJ/bit
ϵ_{mp}	0.0013 pJ/bit/m^4
E_{DA}	5 nJ/bit/signal
P_{opt}	0.1

IV. SIMULATION RESULTS

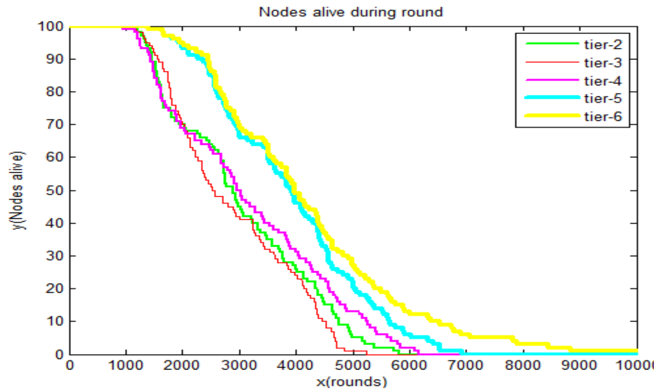

Fig. 3. Nodes alive for network 100x100m with 100 nodes

In this section, performance evaluation of various level of energy distribution in aheterogeneous protocol is done using MATLAB R2013b. We have developed a WSN scenario which consists of randomly deployed sensor nodes. Here, we have not considered the loss of energy because of signal interference and data collision, coming from different nodes because of the dynamic random channel conditions of nodes.

For simulations, we consider different cases for the comparison between various protocols.

1) Case1:

In this case we develop a WSN where 100 sensor nodes are deployed randomly in 100m x 100m area and the number of various nodes by factor m=0.8, m_o=0.4, m_1=0.5, m_2=0.5,and m_3=0.5. The number of normal nodes are 20, advanced nodes are 48, super nodes are, 16 ultra-super nodes are 8, hyper nodes are 4 and the super-hyper nodes are also 4.

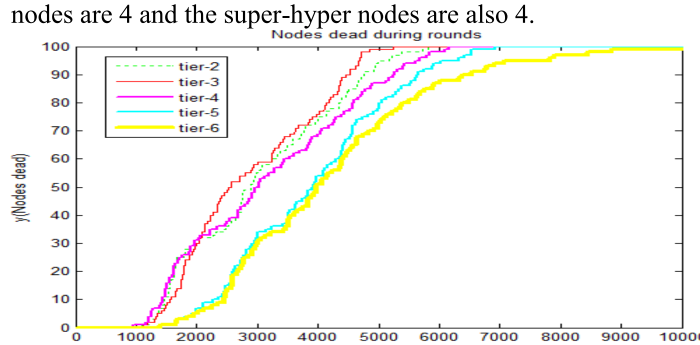

Fig. 4. Nodes dead for network 100x100m with 100 nodes

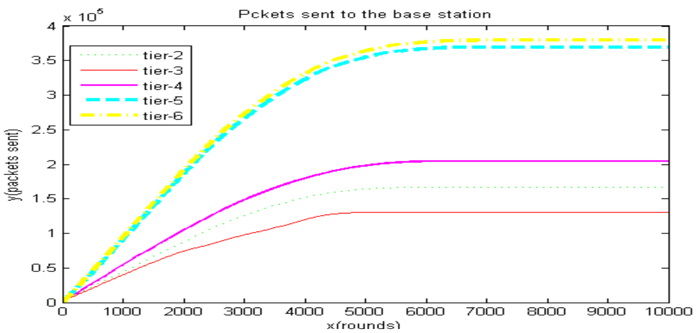

Fig. 5. Throughput for network 100x100m with 100 node

2) Case2:

In case 2, we developed a WSN where we deployed 250 nodes randomly in 250m x 250m area and the number of various nodes by factor m=0.8, m_o=0.4, m_1=0.5, m_2=0.5 and m_3=0.5. The number of normal nodes are 50, advanced nodes are 120, super nodes are, 40 ultra-super nodes are 20, hyper nodes are 10 and the super-hyper nodes are also 10.

3) Case3:

In the case 3, we design a WSN where we deployed 500 nodes randomly in 500m x 500m area and the number of various nodes by factor m=0.8, m_o=0.4, m_1=0.5, m_2=0.5,and m_3=0.5.The number of normal nodes are 100, advanced nodes are 240, super nodes are, 80 ultra-super nodes are 40, hyper nodes are 20 and the super-hyper nodes are also 40.

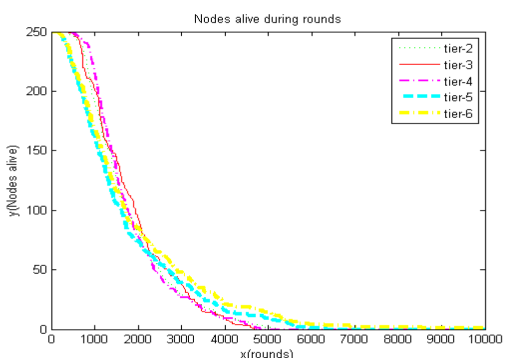

Fig. 6. Nodes alive for network 250x250m with 250 nodes

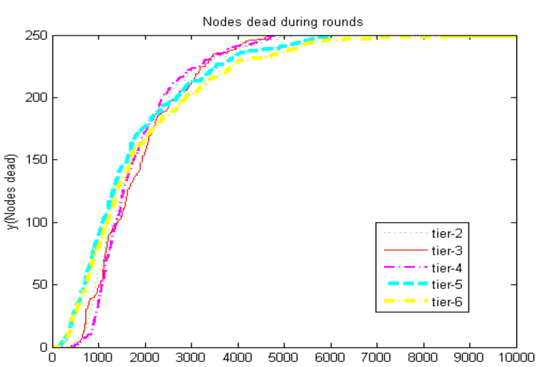

Fig. 7. Nodes dead for network 250x250m with 250 nodes

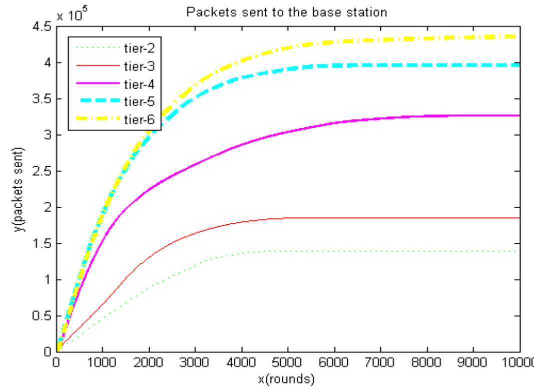

Fig. 8. Throughput for network 250x250m with 250 nodes

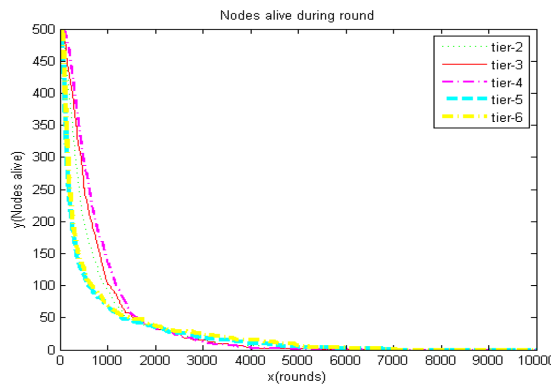

Fig. 9. Nodes alive for network 500x500m with 500 nodes

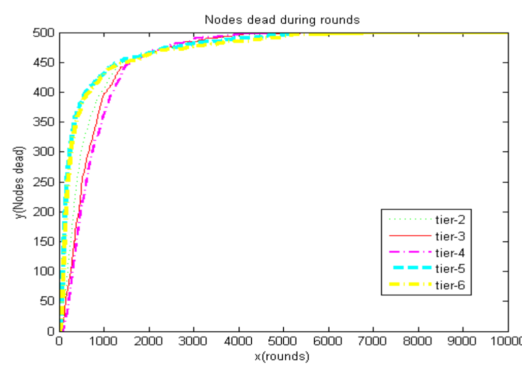

Fig. 10. Nodes dead for network 500x500m with 500 nodes

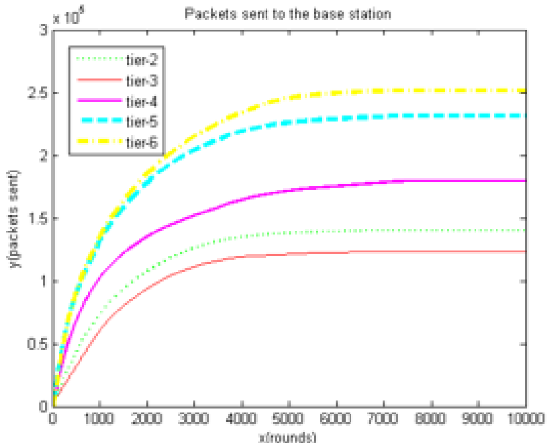

Fig. 11. Throughput for network 500x500m with 500 nodes

V. CONCLUSION AND FUTURE WORK

The heterogeneous energy efficient algorithms are used for improving the lifetime of WSNs by enhancing the level of heterogeneity in the network. In this paper 5 tier and 6 tier of the level of heterogeneity is proposed in the networks and the results are compared with different types of heterogeneous algorithms. It is observed that the results are better than the other existing heterogeneous algorithms. Although heterogeneous algorithms gives a better performance but much remains to be done in this regards especially if we can use the mobile nodes according to the demand of energy in the communication and also use a mobile sink for data collection of the nodes when they are about to die etc. helps in improving the network lifetime.

REFERENCES

[1] S. Lindsey, C.S.Raghavenda, "PEGASIS: power efficient gathering in sensor information systems", in: Proceedings of the IEEE Aerospace Conference, Big Sky, Montana, March [2002].

[2] W.Heinzelman, A.Chandrakasan, H. Balakrishnan, "An application-specific protocol architecture for wireless micro sensor networks", IEEE Transaction on Wireless Communication, vol. 1, no. 4, pp. 660-670, [2002].

[3] G. Smaragdakis, I. Matta, Bestavros, "SEP: A Stable Election protocol for clustered heterogeneous wireless sensor networks", in: second international workshop on sensor and actor network protocols and application, year 2004.

[4] L. Qing, Q.Zhu, M. Wang, "Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor network", ELSEVIER, Computer Communications 29, pp. 2230- 2237, 2006.

[5] Parul Saini, Ajay.K.Sharma, "E-DEEC- Enhanced Distributed Energy Efficient Clustering Scheme for Heterogeneous WSN", in: 2010 1st International Conference on Parallel, Distributed and Grid Computing (PDGC-2010).

[6] BrahimElbhir, Rachidsaadane, Sanaa EL Fkihi, DrissAboutajdine, "Developed Distributed energy- efficient clustering (D-DEEC) for heterogeneous wireless sensor networks", in 5th international symposium on I/V Communications and Mobile Network (ISVC), 2010.

[7] TN Qureshi, N Javaid, AH Khan, A. Iqbal, E Akhtar, M Ishfaq, "BEENISH: Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol for Wireless Sensor Networks", Proc Computer Sci. 19, 920–925 (2013).

[8] A Ahmad, N Javaid, ZA Khan, U Qasim, TA Alghamdi, (ACH)2: routing scheme to maximize lifetime and throughput of WSNs. IEEE Sensors J. 14(10), 3516–3532 (2014). doi:10.1109/JSEN.2014.2328613