Comparative Analysis of Cluster Based Routing Protocols used in Heterogeneous Wireless Sensor Network

Poonam Tyagi, Ravinder Prakash Gupta, Rakesh Kumar Gill

***Abstract*—Energy Efficient are one of the most practical solutions in order to handle with the requirements of large-scale wireless sensor networks (WSN). Energy consumption is one of the basic problem of WSNs. In this paper we have compare the performance of (DEEC) Distributed Energy Efficient routing protocol in terms of energy consumption, alive nodes, and packet transmission .We propose a new approach to exploit efficiently the network energy, by increasing the network lifetime.**

We have used a clustering technique so that the energy consumption of the network decreases, packet transmission increases and alive nodes increases. Simulation results reveal that the lifetime of proposed algorithm is 40% longer than DEEC and shows the no of packets transmission increases as compare to DEEC

***Index Terms*— Wireless Sensor Networks, Clustering Protocol, Energy Efficiency, Cluster-Head Selection, Network lifetime**

I. INTRODUCTION

WSN faces a challenge in energy consumption [1,2] because the sensor nodes in WSN are provided energy by compact batteries and the data transmission is frequent, the energy could be used up in a short time. Therefore, to design a kind of routing protocol that can reduce the energy consumption, and prolong the lifetime of WSN is necessary. Clustering has proven particularly energy efficient in sensor network [3, 4].The network is divided into clusters. Then each cluster is divided into cluster members and a cluster head. The cluster head collects the data from the cluster members and then send it to the base station. The cluster head transmit the data in two ways-inter communication and intra communication. The position of the base station is always in the center of the network so that less power is consumed in data transmission from CH to BS.

In this paper we study the distributed Energy efficient clustering protocol by evaluating alive nodes for network lifetime, energy consumption and packet transmission to cluster head and a new clustering protocol has been introduced which is the improvement on DEEC.

The rest of the paper is organized as pursue. Section 2 describes the Radio energy model and the assumptions used for the work.Section3 DEEC routing protocol and Section 4 proposed algorithm. Simulation results are shown in section 5 .At last section 6 gives conclusion

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II. PURPOSE OF GROUNDING SYSTEM

In our work we assume a radio model [7] with energy dissipated in the transmitting and receiving modes, shown in fig,2.1.In radio energy model energy dissipates to operate the transmitter or receive circuitry Eelec = 50nJ/bit, ϵ_{AMP} =100pJ,data aggregation energy,EDA=5nJ/bit/message,ϵ_{mp}=0.0013pj/bit/m^4,ϵ_{fs}=10pJ/bit/m^2

In this work free space (d^2 power loss) and the multi path fading (d^4 power loss) channel models were used. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used

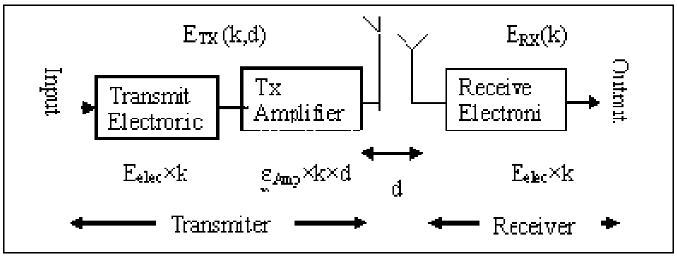

Fig:2.1 Radio Energy Model.

Thus, to transmit an k− bits message over a distance *d*, the radio expends as:

$$E_{TX}(k,d) = E_{TX-elec}(k)+E_{TX-amp}(k,d) \qquad (1)$$

and then :

$$E_{TX}(k,d)=\begin{cases} kE_{elec} + k\,\epsilon_{fs}\,d^2 & if\ d < d_0 \\ kE_{elec} + k\,\epsilon_{mp}\,d^4 & if\ d \geq d_0 \end{cases} \qquad (2)$$

Where the threshold d_o is defined by (3):

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \qquad (3)$$

The electronics energy depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal, whereas the amplifier energy,$\epsilon_{fs}d^2$or $\epsilon_{mp}d^4$, depends on the distance to the receiver and the acceptable bit-error rate .To receive this message the radio expends energy:

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$$E_{RX}(k) = k\, E_{elec} \quad (4)$$

We have assumed that the radio channel is symmetric such that the energy needed to transmit a message from node 1 to node 2 is the same as the energy required to transmit a message from node 2 to node 1 for a given SNR.

Assumptions

Here in this section, heterogeneous network model has been assumed which exists practically. Let there are *S* total number of nodes which are distributed randomly within a $N \times N$ square region as shown in Figure 2. Before we detail our protocol, we make the following assumptions:

1) All nodes in the network are Heterogeneous
2) Base station is fixed and located at the centre of the network area.
3) The data packet length is *k* bits.
4) All the network nodes can reach the base station.
5) CHs can transmit data to the BS
6) Cluster members send their data to the CHs to which they belong.
7) Every sensor node is having a data packet to transmit in a fixed time.
8) All the sensor nodes are assumed to be stationary.
9) Sensing range of node is a smaller than the transmission range.

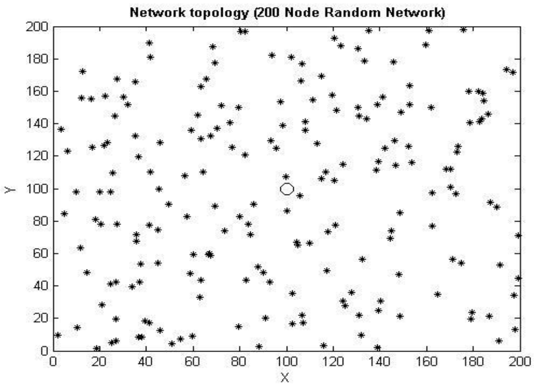

Fig: 2.2 Random Network

III. DESCRIPTION OF DEEC PROTOCOL

DEEC [11] is a distributed energy efficient clustering protocol for heterogeneous wireless sensor networks. In this cluster-heads are selected by a probability based on the ratio between remaining energy of each node and the average energy of the network. The epochs of being cluster-heads for nodes are different according to their initial and remaining energy. The nodes which have high initial and remaining energy will have more chances to be the cluster-heads than the nodes with low energy. There are two types of heterogeneous networks i.e. two-level heterogeneous network and multi-level heterogeneous network. In this work we consider multi-level heterogeneous network model. In heterogeneous network there are two types of sensor nodes i.e. advanced nodes and normal nodes. Let *E*0 is the initial energy of the normal nodes and *m* is the fraction of advanced nodes which own *a (additional energy factor between advanced and normal nodes)* times more energy than normal nodes. Thus there are *mN* advanced nodes equipped with *E*0 (1 + *a*) initial energy and *N* (1 – *m*) normal nodes equipped with *E*0 initial energy. Thus total initial energy for two-level heterogeneous network is given by:

$$E_{total} = N\,(1-m)\,E0 + Nm\,E0(1+a) = NE0\,(1+am) \quad (5)$$

In multi-level heterogeneous network, initial energy of nodes randomly distributed over the close set [*E*0, *E*0 (1 +a_{max}]. Thus total initial energy is computed as:

$$E_{total} = \sum_{i=1}^{N} E_0(1+a_i) = E_0(N + \sum_{i=1}^{N} a_i) \quad (6)$$

As in two-level heterogeneous networks, the clustering algorithm should consider the discrepancy of initial energy in multi-level heterogeneous networks.

A. Cluster –head selection

Let n_i denote the number of rounds to be a cluster-head for the node si, and we refer to it as the rotating epoch. Let each node s_i ($i = 1, 2, \ldots, N$) becomes a cluster-head once every $n_i = 1/p_{opt}$ rounds., we choose different n_i based on the residual energy $E_i(r)$ of node s_i at round *r*. Let $p_i = 1/n_i$, is average probability to be a cluster-head during n_i rounds. Nodes have different amounts of energy; p_i of the nodes with more energy should be larger than p_{opt}. Let $\overline{E}(r)$ denote the average energy at round r of the network, which can be obtained by

$$\bar{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \quad (7)$$

To compute $\overline{E}(r)$ by Eq. (7), each node should have the knowledge of the total energy of all nodes in the network. Using $\overline{E}(r)$ to be the reference energy, we have

$$p_i = p_{opt}\left[1 - \frac{\bar{E}(r) - E_i(r)}{\bar{E}(r)}\right] = p_{opt}\frac{Ei(r)}{\bar{E}(r)} \quad (8)$$

This guarantees that the average total number of cluster-heads per round per epoch is equal to:

$$\sum_{i=1}^{N} pi = \sum_{i=1}^{N} p_{opt}\frac{Ei(r)}{\bar{E}(r)}$$

$$= p_{opt}\sum_{i=1}^{N}\frac{Ei(r)}{\bar{E}(r)} = Np_{opt} \quad (9)$$

It is the optimal cluster-head number which is to achieve. The probability threshold that each node s_i use to determine whether itself to become a cluster-head in each round, is as follows

$$T(s_i) = \begin{cases} \dfrac{p_i}{1 - p_i(r \bmod \frac{1}{p_i})} & \text{if } s_i \in G \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

Where G is the set of nodes that are suitable to be cluster-heads at round *r*. If node s_i has not been a cluster-head during the most recent n_i rounds, we have $s_i \in G$ If the number is less than threshold $T(s_i)$, the node s_i becomes a cluster-head during the current round.

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B. Coping with Heterogeneous Nodes

From Eq.8, it is seen that p_{opt} is the reference value of the average probability p_i, which determine the rotating epoch n_i and threshold $T(s_i)$ of node s_i.. In the heterogeneous network, the reference value of each node should be different according to the initial energy. In the two-level heterogeneous networks, weighted probabilities (eq.11) are taken for normal and advanced nodes [4].

$$p_{adv} = \frac{p_{opt}}{1+am},$$
$$p_{nrm} = \frac{p_{opt}(1+a)}{(1+am)} \quad (11)$$

Therefore p_i is changed into

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \dfrac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{if } s_i \text{ is the advanced node} \end{cases}$$

(12)

Substituting Eq. (13 for p_i in Eq. (10)), we can get the probability threshold used to elect the cluster-heads. This model can be easily extended to multi-level heterogeneous networks. The weighted probability for any sensor node is expressed as

$$p(s_i) = \frac{p_{opt}N(1+a_i)}{\left(N + \sum_{i=1}^{N} a_i\right)} \quad (13)$$

This equation is used to replace p_{opt} of Eq. (8) and obtain the p_i for heterogeneous nodes as

$$p_i = \frac{p_{opt}N(1+a)E_i(r)}{(N + \sum_{i=1}^{N} a_i)\bar{E}(r)} \quad (14)$$

From Eqs. (13) and (14),

$$I_i = \frac{(N + \sum_{i=1}^{N} a_i)}{p_{opt}N(1+a_i)} \quad (15)$$

Expresses the basic rotating epoch of node s_i, and it is called as reference epoch.

C. Average Energy of the Network

From Eqs. (12) and (14), the average energy $\bar{E}(r)$ is needed to compute the average probability p_i. so that we have estimate the $\bar{E}(r)$ .As shown in Eqs. (8) and (11), the average energy $\bar{E}(r)$ is just used to be the reference energy for each node. We can estimate the average energy $\bar{E}(r)$ of rth round as follow.Let E_{round} denote the energy consumed by the network in each round. R can be approximated as follow

$$\bar{E}(r) = \frac{1}{N} E_{total}\left(1 - \frac{r}{R}\right) \quad (16)$$

Where R denotes the total rounds of the network lifetime. Let E_{round} denote the energy consumed by the network in each round. R can be approximated as follow

$$R = \frac{E_{total}}{E_{round}} \quad (17)$$

Thus the total energy dissipated in the network during a round is equal to:

E_{round} =K(2N E_{elec} +N E_{DA} +C ϵ_{mp} d^4 toBS +Nϵ_{fs} d^2toCH) (18)

Where C is the number of clusters,

E_{DA} is the data aggregation cost expended in the cluster-heads,

d_{toBS} is the average distance between the cluster-head and the base station,

d_{toCH} is the average distance between the cluster members and the cluster-head. Thus we get

$$d_{toCH} = \frac{N}{\sqrt{2\pi k}},$$
$$d_{toBS} = 0.765\frac{N}{2} \quad (19)$$

By setting the derivative of E_{round} with respect to k to zero, we have the optimal number of clusters as

$$k_{opt} = \frac{\sqrt{S}}{\sqrt{2\pi}} \frac{\sqrt{\varepsilon_{fs}}}{\sqrt{\varepsilon_{mp}}} \frac{N}{d^2_{toBS}} \quad (20)$$

Substituting Eqs. (19) and (20) into Eq. (18), we obtain the energy E_{round} dissipated during a round.

IV. PROPOSED ALGORITHM

The Algorithm proposed in this section is the improvement on DEEC protocol. It is named as Improved Distributed Energy Efficient clustering protocol for Routing in Wireless Sensor Network. The operation of iDEEC is divided in to two phases.

A. Setup Phase

In this phase cluster formation takes place. For every transmission round the node si calculate the probability threshold T(si) and choose random number between 0 and 1 same as DEEC. If the number is less than threshold T(si), the node si becomes a cluster-head during the current round. The CHs then broadcast the message to the network and declare themselves as cluster heads. After this message, each regular node chooses its closest cluster head with the largest received signal strength and then informs the cluster head by sending a JOIN_CLU (join cluster) message. If no message is broadcast from any cluster-head, it makes itself as cluster-head. The cluster head sets up a TDMA schedule and transmits it to the nodes in the cluster.After the TDMA schedule is known by all nodes in the cluster, the set up phase is completed and the next phase begins.

B. Steady State Phase

This is most important phase of our algorithm which differentiate i-DEEC from DEEC.Once the clusters are established, the nodes transmit their data messages towards the cluster-head. In this phase, before communication, the proposed algorithm checks whether the node is cluster-head or a cluster member which is not in DEEC. This helps the CH in preventing to pass the packet to itself because it is of no logic. Thus cluster-head communicates with its cluster members and BS only. Within the cluster, the communication uses TDMA, as described in the set up phase. When the cluster-head receives all the nodes data, it performs its compression, to form a new message that sent to the base station.

V. SIMULATION RESULTS

In this section, we compare the performance of DEEC and iDEEC using MATLAB in terms of energy consumption, packet transmission and alive nodes..The parameters values used for simulation are shown in table. The random network used in simulation has 200 nodes which are randomly distributed over 200m×200m square region. Base station is located in center of the network region.

Table 5. 1 Simulation parameter

Description	**Value**
Network Grid	From(0,0)to(200,200)
Base Station	100
Threshold Distance	87m
Data packet size	2000
Optimal probability	0.1
r (no. of rounds)	4000
Eo	0.5J
a	1

For analyzing the performance of any routing protocol lesser energy consumption is the main issue so that the network stays alive for longer period or for more number of rounds.
iDEEC consumes less energy in comparison to DEEC which helps to extend the network lifetime. Fig 5.1 shows the approximately 20% of energy is saved by using iDEEC.

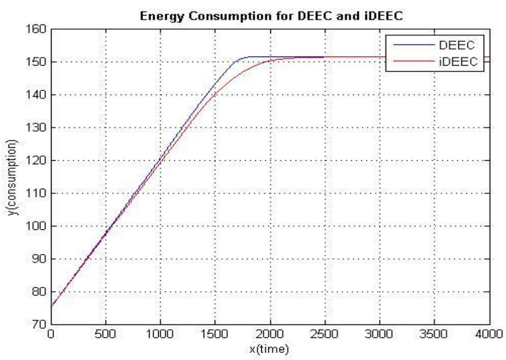

Fig:5.1 Energy Consumption

Fig:5.2 shows the comparision graph of DEEC and iDEEC showing number of alive nodes w.r.t no of rounds.The nodes which can participate in the communication and the nodes whose energy has not reduced to zero are referred as alive nodes. This parameter also helps in evaluating the network lifetime.
This graph shows the number of alive nodes during each transmission round for the iDEEC and DEEC routing protocol. Thus the graph shows that nodes alive upto round r = 1850 in DEEC and in iDEEC nodes remain alive up to 3250 round thus this shows that in iDEEC the nodes remain alive for longer time in comparison to DEEC routing protocol.

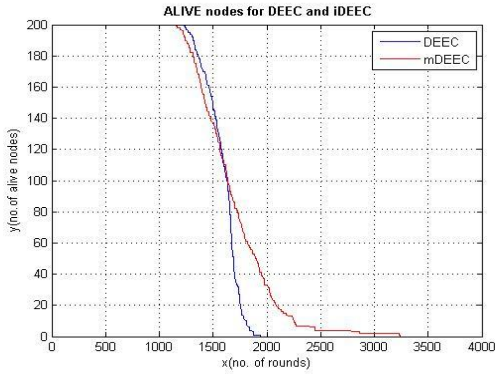

Fig:5.2 Alive Nodes

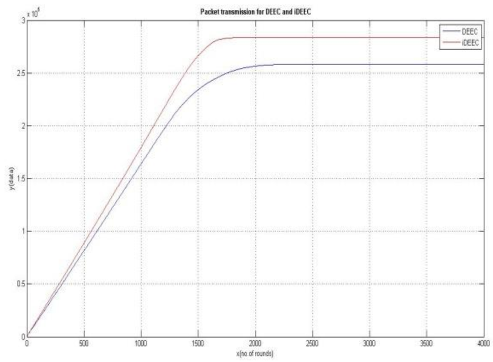

Fig.5.3 Packet Transmission

Fig:5.3 gives the graph for packet transmission .As explained before that in iDEEC, it checked first that the node transmitting a message is cluster-head or not and if that node is CH then it will send that to the BS directly rather than to CH i.e. itself. But in DEEC the node is not checked before transmission. Thus in iDEEC, more number of packets are transmitted to BS.

VI. CONCLUSION

In this paper, iDEEC has been proposed, examined and compared with the DEEC routing protocol. Although both the protocols perform well in multi-level heterogeneous networks but the proposed algorithm shows better performance in terms of energy saving, alive nodes and packet transmission.

Through the simulation, it is demonstrated that the proposed algorithm allows a large stable network lifetime in comparison to the DEEC routing protocol.

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