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Threshold Sensitive Distributed Energy Efficient Clustering Routing Protocol For Wireless Sensor Networks

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Abstract: *Wireless sensor networks(WSN) consists of widespread random deployment of energy constrained sensor nodes ,many routing protocols have been proposed based on heterogeneity with main research goals such as achieving the energy efficiency, lifetime, and deployment of nodes. In this paper, we have proposed an energy efficient cluster head scheme, for heterogeneous wireless sensor networks, by modifying the threshold value of a node based on which it decides to be a cluster head or not, called TDEEC (Threshold Distributed Energy Efficient Clustering) protocol. Simulation results show that proposed algorithm TDEEC performs better than DEEC , DDEEC and EDEEC.*

Keywords: Cluster-Head (CH), Wireless sensor Network(WSN), Energy Efficiency, (DEEC) Distributed Energy Efficient Clustering, (DDEEC) Developed Distributed Energy Efficient Clustering, (EDEEC) Enhanced Distributed Energy Efficient Clustering.

1. INTRODUCTION

Wireless sensor networks is the network consisting of hundreds of compact and tiny sensor nodes which senses the physical environment in terms of temperature, humidity, light, sound, vibration, etc. These sensor nodes gather the data from the sensing field and send this information to the end user. These sensor nodes can be deployed on many applications. Current wireless sensor network is working on the problems of low-power communication, sensing, energy storage, and computation. Hierarchical-based routing is a cluster based routing in which high energy nodes are randomly selected for processing and sending data while low energy nodes are used for sensing and send information to the cluster heads. Clustering technique enables the sensor network to work more efficiently. It increases the energy consumption of the sensor network and hence the lifetime [1].

2. DEEC

DEEC is designed to deal with nodes of heterogeneous WSNs. For CH selection, DEEC uses initial and residual energy level of nodes. Let n_i denote the number of rounds to be a CH for node s_i. $p_{opt}N$ is the optimum number of CHs in our network during each round. CH selection criteria in DEEC is based on energy level of nodes. As in homogenous network, when nodes have same amount of energy during each epoch then choosing $p_i = p_{opt}$ assures that $p_{opt}N$ CHs during each round. In WSNs, nodes with high energy are more probable to become CH than nodes with low energy but the net value of CHs during each round is equal to $p_{opt}N$. pi is the probability for each node s_i to become CH, so, node with high energy has larger value of pi as compared to the p_{opt}. E(r) denotes average energy of network during round r which can be given as in :

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

Probability for CH selection in DEEC is given as

$$p_i = p_{opt}\left[1 - \frac{\overline{E}(r) - E_i(r)}{\overline{E}(r)}\right] = p_{opt}\frac{E_i(r)}{\overline{E}(r)}. \quad (2)$$

In DEEC the average total number of CH during each round is given as

$$\sum_{i=1}^{N} p_i = \sum_{i=1}^{N} p_{opt}\frac{E_i(r)}{\overline{E}(r)} = p_{opt}\sum_{i=1}^{N}\frac{E_i(r)}{\overline{E}(r)} = Np_{opt}. \quad (3)$$

pi is probability of each node to become CH in a round where G is the set of node eligible to become CH at round r. If node becomes CH in recent rounds then it belongs to G. During each round each node chooses a random number between 0 and 1. If number is less than threshold as defined below, it is eligible to become a CH else not.

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i\left(r \bmod \frac{1}{p_i}\right)} & \text{if } s_i \in G \\ 0 & \text{otherwise} \end{cases}, \quad (4)$$

As p_{opt} is reference value of average probability pi. In homogenous networks, all nodes have same initial energy so they use p_{opt} to be the reference energy for probability pi. However in heterogeneous networks, the value of p_{opt} is different according to the initial energy of the node. In two level heterogeneous network the value of p_{opt} is given by

$$p_{adv} = \frac{p_{opt}}{1 + am}, \quad p_{nrm} = \frac{p_{opt}(1 + a)}{(1 + am)}. \quad (5)$$

Then use the above p_{adv} and p_{nrm} instead of p_{opt} in equation (2) for two level heterogeneous network as

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+am)\overline{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{p_{opt}(1+a)E_i(r)}{(1+am)\overline{E}(r)} & \text{if } s_i \text{ is the advanced node} \end{cases} \quad (6)$$

Above model can also be extended to multi level heterogeneous network given below as

$$p_{multi} = \frac{p_{opt} N(1 + a_i)}{(N + \sum_{i=1}^{N} a_i)} \quad (7)$$

Above p_{multi} in equation (2) instead of p_{opt} to get pi for heterogeneous node pi for the multilevel heterogeneous network is given by

$$p_i = \frac{p_{opt} N(1 + a)E_i(r)}{(N + \sum_{i=1}^{N} a_i)\bar{E}(r)} \quad (8)$$

In DEEC we estimate average energy E(r) of the network for any round r as

$$E(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R}\right) \quad (9)$$

R denotes total rounds of network lifetime and is estimated as follows:

$$R = \frac{E_{total}}{E_{round}} \quad (10)$$

E_{total} is total energy of the network where E_{round} is energy expenditure during each round.

3. DDEEC

DDEEC implements the same strategy like DEEC en terms of estimating average energy of networks and the cluster head selection algorithm which is based on residual energy where:

- The average energy of r_{th} round is set at eq(9). where R denote the total rounds of the network lifetime and is defined at equation(10).
- E_{Round} is the total energy dissipated in the network during a round, is equal to:

$$E_{round} = L(2*N*E_{elec} + N*E_{DA} + k*\varepsilon mp*d^4_{toBs} + N*\varepsilon f*d^2_{toCh}) \quad (11)$$

Where k 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, and d_{toCH} is the average distance between the cluster members and the cluster head.

- Because we assuming that the nodes are uniformly distributed, we can get:

$$d_{toCH} = M/\sqrt{2\pi k},\ d_{toBS} = 0.765*M/2 \quad (12)$$

- The optimal number of clusters is defined as:

$$k_{opt} = \frac{M}{d^2_{toBS}} \frac{\sqrt{N}}{\sqrt{2\pi}} \frac{\sqrt{Efs}}{\sqrt{Emp}} \quad (13)$$

In this way, we continue to punish more just these nodes, so they spent more energy and they will die quickly 1. To avoid this unbalanced case, our protocol DDEEC introduce some changes on the equation 6. These changes is based on using a threshold residual energy value Th_{REV} , which is equal to:

$$Th_{REV} = Eo\left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}}\right) \quad (14)$$

Therefor, the cluster head election will be balanced and more equitable. So, the equation (6) which represents the nodes average probability pi to be a cluster head will changed as fellow:

$$p_i = \begin{cases} \frac{p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{for Nml nodes, } E_i(r) > Th_{REV} \\ \frac{(1+a)p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{for Adv nodes, } E_i(r) > Th_{REV} \\ c\frac{(1+a)p_{opt} E_i(r)}{(1+am)\bar{E}(r)} & \text{for Adv, Nml nodes, } E_i(r) \le Th_{REV} \end{cases} \quad (15)$$

The value of Th_{REV} is written as $Th_{REV} = b_{Eo}$ where

$$b = \left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}}\right) \quad (16)$$

4. EDEEC

E-DEEC implements the same strategy for estimating the energy in the network as proposed in DEEC .

Since the probabilities calculated depend on the average energy of the network at round r, hence this is to be calculated. This average energy is estimated in equation(9).

Where R denotes the total rounds of the network lifetime. R can be calculated in equation (10).

d_{toBS} & d_{toCH} is calculated in equation (12) .

During each round , node decide whether to become a CH or not based on threshold calculated by suggested percentage of CH and the number of times the node has been a CH so far. This decision is taken by nodes by choosing a random number between 0 & 1. If number is less than threshold T(s), the node become a CH for current round. Threshold is calculated as:

$$T(s) = \begin{cases} \frac{p}{1 - p.(r \bmod \frac{1}{p})} & \text{if } s \in G \\ 0 & \text{Otherwise} \end{cases} \quad (17)$$

where p, r, and G represent, respectively, the desired percentage of cluster-heads, the current round number, and the set of nodes that have not been cluster-heads in the last 1/p rounds. Using this threshold, each node will be a cluster head, just once at some point within 1/p rounds. In the three level heterogeneous networks there are three types of nodes normal nodes, advanced nodes and super nodes, based on their initial energy. Hence the reference value of p is different for these types of nodes. The probabilities of normal, advanced and super nodes are:

$$p_i = \begin{cases} \frac{p_{opt} E_i(r)}{(1+m.(a+mo.b))\bar{E}(r)} & \text{if } s_i \text{ is the normal node} \\ \frac{p_{opt}(1+a)E_i(r)}{(1+m.(a+mo.b))\bar{E}(r)} & \text{if } s_i \text{ is the advanced node} \\ \frac{p_{opt}(1+b)E_i(r)}{(1+m.(a+mo.b))\bar{E}(r)} & \text{if } s_i \text{ is the super node} \end{cases} \quad (18)$$

Threshold for cluster head selection is calculated for normal, advanced, super nodes by putting above values in Equation(17)

$$T(s_i)=\begin{cases} \frac{p_i}{1-p_i\cdot\left(r \bmod \frac{1}{p_i}\right)} & \text{if } p_i \in G' \\ \frac{p_i}{1-p_i\cdot\left(r \bmod \frac{1}{p_i}\right)} & \text{if } p_i \in G'' \\ \frac{p_i}{1-p_i\cdot\left(r \bmod \frac{1}{p_i}\right)} & \text{if } p_i \in G''' \\ 0 & \text{Otherwise} \end{cases} \quad (19)$$

where G' is the set of normal nodes that have not become cluster heads within the last 1/pi rounds of the epoch where s_i is normal node, G'' is the set of advanced nodes that have not become cluster heads within the last 1/pi rounds of the epoch where s_i is advanced node, G'' is the set of super nodes that have not become cluster heads within the last 1/pi rounds of the epoch where s_i is super node.

5. TDEEC

Our approach is minimize transmission time in the network. The basic theory is that clustering is done because the nodes which are clustered have a sensed data which vary in very insignificant amount. So cluster head in a cluster when take the data from their members is similar in nature. Cluster heads have to send similar type of data. Again and again to base station which is time consuming and wastage of energy by the cluster heads. This concept was explored in detail in TEEN which imposed two thresholds hard and soft threshold which optimized the communication and prolong the life of the network. We tried to use the optimization Protocol TEEN on enhanced version of DEEC i.e. EDEEC. But we according to our scheme we first increased the stability period by introducing a new node "super advanced" in our network. Introducing a node increased the heterogeneity to level four but thing is that it is not using nodes having energy more than super nodes as in EDEEC. So nodes are in our scheme are

$$\text{normal nodes: } E_0$$
$$\text{advanced nodes: } E_0(1+a)$$
$$\text{super nodes: } E_0(1+b)$$
$$\text{superadvanced nodes: } E_0(1+c)$$
$$\text{Where } a=\frac{c}{2};\ b=\frac{3c}{4};\ c=1$$

Here P_{opt} is probability of choosing the cluster heads in the network so a node become eligible for cluster head again after 1/p0 rounds. So average no of cluster heads should be $n*p_{opt}$ if n is total no of nodes. In our scheme nodes are distributed according to constant m and m0 and nodes are:

$$\text{normal nodes} = (1-m)*n$$
$$\text{advanced nodes} = (1-m0)*m*n$$
$$\text{super nodes} = (m0*m*n)/2$$
$$\text{superadvanced nodes} = (m0*m*n)/2$$

Therefore total energy of the network in a round is

$$E_0*(1-m)*n+E_0(1+a)*(1-m0)*m*n+E_0(1+b)*\frac{m0*m*n}{2}+E_0(1+c)*\frac{m0*m*n}{2}=n*E_0\left(1+a*m-m*m0*\left(a-\left(\frac{b+c}{2}\right)\right)\right) \quad (20)$$

So, weighed probabilities of different nodes are

$$p_{norm}=\frac{p_{opt}}{\left(1+a*m-m*m0*(a-(\frac{b+c}{2}))\right)}$$
$$p_{adv}=\frac{p_{opt}(1+a)}{\left(1+a*m-m*m0*(a-(\frac{b+c}{2}))\right)}$$
$$p_{super}=\frac{p_{opt}(1+b)}{\left(1+a*m-m*m0*(a-(\frac{b+c}{2}))\right)}$$
$$p_{sadv}=\frac{p_{opt}(1+c)}{\left(1+a*m-m*m0*(a-(\frac{b+c}{2}))\right)} \quad (21)$$

Ultimately our new threshold for deciding the cluster heads election is as:

$$T(i)=\begin{cases} \frac{p_{norm}}{1-p_{norm}\left(r\times \bmod\left(\frac{1}{p_{norm}}\right)\right)} & \text{if } i \text{ is normal node and } i\in G \\ \frac{p_{adv}}{1-p_{adv}\left(r\times \bmod\left(\frac{1}{p_{adv}}\right)\right)} & \text{if } i \text{ is advance node and } i\in G' \\ \frac{p_{super}}{1-p_{super}\left(r\times \bmod\left(\frac{1}{p_{super}}\right)\right)} & \text{if } i \text{ is super node and } i\in G'' \\ \frac{p_{sadv}}{1-p_{sadv}\left(r\times \bmod\left(\frac{1}{p_{sadv}}\right)\right)} & \text{if } i \text{ is superadvanced node and } i\in G''' \\ 0 & \text{otherwise} \end{cases} \quad (22)$$

Now, cluster heads are made according to equation (22). We randomly take a number g between [0, 1]. If the threshold T (i) for i^{th} node is greater than g and node i e ongs to set (G or G' or G'' or G''') then it become cluster head otherwise it will be a simple node. Here G, G', G'' and G''' are set of normal , advanced, super and superadvanced nodes respectively which has not become cluster heads yet. Cluster heads gather the data from its cluster members and they will not send sensed data to Base station as they receive the value. The TEEN is implemented in the nodes. These cluster heads nodes store two threshold hard and soft thresholds. Hard threshold (h) is calculated over highest and lowest value sensed by the nodes. For example in temperature sensing Applications the hard threshold is calculated as the average of maximum temperature sensed and minimum temperature sensed. In our scenario we have simulated

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our network as temperature sensing wireless sensor network and hard Threshold is taken as 100 (in degree Celsius). Also, we are using the term data for the temperature sensed by the nodes. The sensed value is stored as a variable in the node, called effective sensed value(SV). The nodes will next transmit data only when the following conditions are met:

1. The current value of the sensed data (CV) is greater than the hard threshold.(CV>h) and

2. The current value of the sensed attribute (CV) differs from SV by an amount equal to or greater than the soft threshold (diff=CV-SV).

Whenever a node transmits data, SV become the current value of the sensed attribute. Here, in this scheme we have taken s=2(in degree Celsius). These thresholds are making our scheme to work in reactive way as TEEN as Transmission is not periodically as in LEACH, SEP. The transmission of data is done after receiving the value and applying the thresholds. So data is sent in a non-periodically fashion according to importance of the sensed data. Thus our scheme TDEEC optimized the communication in the networks and makes the communication energy-efficient.

6. RESULTS & DISCUSSIONS

This section presents simulation result for DEEC, DDEEC, EDEEC,TDEEC and Proposed protocol for three level heterogeneous WSN using MATLAB.
Performance parameters used for evaluation of clustering protocols for heterogeneous WSNs are lifetime of heterogeneous WSNs, number of nodes alive during rounds and data packets sent to BS.

- ***Lifetime*** is a parameter which shows that node of each type has not yet consumed all of its energy.
- ***Number of nodes alive*** is a parameter that describes number of alive nodes during each round.
- ***Data packets sent to the BS*** is the measure that how many packets are received by BS for each round.

Table 1. Simulation Parameters

Parameter	Value
Network Field	(100m , 100m)
Eo(Initial energy of the Normal Node)	0.5J
Message Size(L)	4000bits
Eelec	50nJ/bit
ϵfs	10 pJ/bit/m2
ϵamp	0.013 pJ/bit/m4
EDA	5 nJ/bit/signal
do(Threshold Distance)	70m
Pop(Suggested Percentage)	0.1
Number of Nodes (N)	100

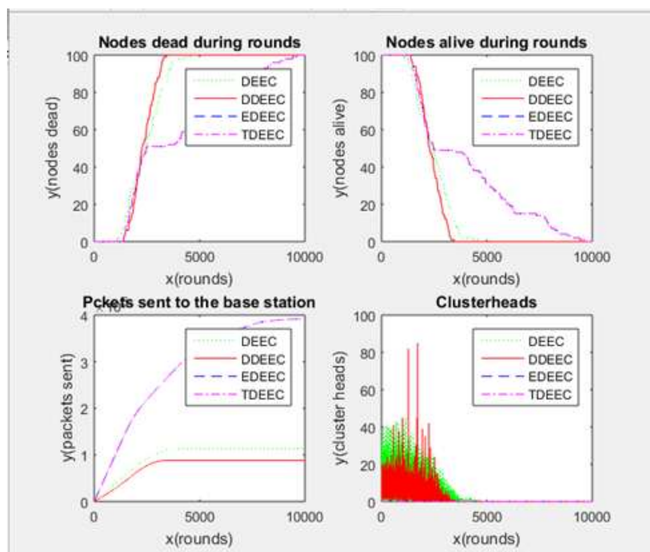

Fig.1 Dead Nodes, Alive Nodes, Packet sends to BS Nodes, Count of Cluster Head per round during 10000 rounds and 100 nodes

7. Acknowledgment

In this paper we proposed TDEEC (Threshold Distributed Energy Efficient Clustering) protocol which improves stability and energy efficient property of the heterogeneous wireless sensor network and hence increases the lifetime. Simulation results show that TDEEC performs better as compared to DEEC , DDEEC and EDEEC in heterogeneous environment for wireless sensor networks.

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