Performance Evaluation of Clustered Based Routing Protocol for Wireless Sensor Network

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Abstract - **In this paper performance of the clustered based routing protocols for WSN in saving energy for heterogeneous wireless sensor networks. In the sensor network considered each node transmits sensing data to the base station through a cluster-head. The cluster-heads, which are elected periodically by certain clustering algorithms, aggregate the data of their cluster members and send it to the base station, from where the end-users can access the data. The cluster based protocol has been carried out using NS 2.35.**

Keywords: **LEACH, DEEC, WSN, Routing Protocol**.

I. INTRODUCTION

The nodes of the sensor network are equipped with different amount of energy, which is a source of heterogeneity. It could be the result of reenergizing the sensor networks in order to extend the network lifetime. The new nodes added to the networks will own more energy than the old ones. Even though the nodes are equipped with the same energy at the beginning, the networks cannot evolve equably for each node in expending energy, due to the radio communication characteristics, random events such as short-term link failures or morphological characteristics of the field[9]. Therefore, WSN are more possibly heterogeneous networks than homogeneous ones. The protocols should be fit for the characteristic of heterogeneous wireless sensor networks. Currently, most of the clustering algorithms, such as LEACH PEGASIS [11], and HEED [12], all assume the sensor networks are homogeneous networks. These algorithms perform poorly in heterogeneous environments. The low-energy nodes will die more quickly than the high-energy ones, because these clustering algorithms are unable to treat each node discriminatorily in term of the energy discrepancy. In[9], SEP scheme is proposed for the two-level heterogeneous wireless sensor networks, which is composed of two types of nodes according to the initial energy. The advance nodes are equipped with more energy than the normal nodes at the beginning. SEP prolongs the stability period, which is defined as the time interval before the death of the first node. However, it is not fit for the widely used multi-level heterogeneous wireless sensor networks, which include more than two types of nodes. In this project, we propose and evaluate a new distributed energy-efficient clustering scheme for heterogeneous wireless sensor networks, which is called DEEC. Following the thoughts of LEACH, DEEC lets each node expend energy uniformly by rotating the cluster-head role among all nodes. In DEEC, the cluster-heads are elected by a probability based on the ratio between the residual energy of each node and the average energy of the network. The round number of the rotating epoch for each node is different according to its initial and residual energy, i.e., DEEC adapt the rotating epoch of each node to its energy. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes. Thus DEEC can prolong the network lifetime, especially the stability period, by heterogeneous-aware clustering algorithm. Simulations show that DEEC achieves longer network lifetime and more effective messages than other classical clustering algorithms in two-level heterogeneous environments. Moreover, DEEC is also fit for the multilevel heterogeneous networks and performs well, while SEP only operates under the two-level heterogeneous networks.

II. DEEC PROTOCOL

In this section, we present the detail of our DEEC protocol. DEEC uses the initial and residual energy level of the nodes to select the cluster-heads. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is use to compute the reference energy that each node should expend during a round Cluster-head selection algorithm based on residual energy Let n_i denote the number of rounds to be a cluster head for the node s_i , and we refer to it as the rotating epoch. In homogenous networks, to guarantee that there are average p_{opt} N cluster-heads every round, LEACH let each node s_i (i=1,2,...,N) becomes a cluster-head once every $n_i = 1/p_{opt}$ rounds. Note that all the nodes cannot own the same residual energy when the network evolves. If the rotating epoch ni is the same for all the nodes as proposed in LEACH, the energy will be not well distributed and the low-energy nodes will die more quickly than the high-energy nodes. In our DEEC protocol, we choose different ni based on the residual energy E_i (r) of node s_i at round r.

Let $p_i = 1/ni$, which can be also regarded as average probability to be a cluster-head during n_i rounds. When nodes have the same amount of energy at each epoch, choosing the average probability pi to be p_{opt} can ensure that there are p_{opt} N cluster-heads every round and all nodes die approximately at the same time. If nodes have different amounts of energy, p_i of the nodes with more energy should be larger than popt. Let E(r) denote the average energy at round r of the network, which can be obtained by

$$\overline{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r). \quad \text{…. (3)}$$

To compute E(r) by Eq. (3), each node should have the knowledge of the total energy of all nodes in the network. We will give an estimate of E (r)Þ in the latter subsection of this section. Using E(r) to be the reference energy, we have

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

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

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

It is the optimal cluster-head number we want to achieve. We get the probability threshold, that each node s_i use to determine whether itself to become a cluster-head in each round, as follow

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

$$R = \frac{E_{\text{total}}}{E_{\text{round}}}.$$

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

Where G is the set of nodes that are eligible to be cluster heads at round r. If node si has not been a cluster-head during the most recent ni rounds, we have si 2G. In each round r, when node si finds it is eligible to be a cluster-head, it will choose a random number between 0 and 1. If the number is less than threshold $T(s_i)$, the node s_i becomes a cluster-head during the current round.

Note the epoch n_i is the inverse of pi From Eq. (4), n_i is chosen based on the residual energy E_i (r) at round r of node s_i as follow

$$n_i = \frac{1}{p_i} = \frac{\overline{E}(r)}{p_{\text{opt}}E_i(r)} = n_{\text{opt}}\frac{\overline{E}(r)}{E_i(r)},$$

Where $n_{opt}=1/p_{opt}$ denote the reference epoch to be a cluster-head. Eq. (7) shows that the rotating epoch n_i of each node fluctuates around the reference epoch. The nodes with high residual energy take more turns to be the cluster-heads than lower ones.

a. Coping with heterogeneous nodes

From Eq. (4), we can see 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 homogenous networks, all the nodes are equipped with the same initial energy, thus nodes use the same value p_{opt} to be the reference point of p_i. When the networks are heterogeneous, the reference value of each node should be different according to the initial energy. In the two-level heterogeneous networks, we replace the reference value p_{opt} with the weighted probabilities given in Eq.(8) for normal and advanced nodes [9].

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

Therefore, p_i is changed into

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

Substituting Eq.(9)forpi on(6), we can get the probability threshold used to elect the cluster-heads. Thus the threshold is correlated with the initial energy and residual energy of each node directly.

This model can be easily extended to multi-level heterogeneous networks. We use the weighted probability shown in Eq. (10)

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

to replace p_{opt} of Eq.(4) and obtain the p_i for heterogeneous nodes as

$$p_i = \frac{p_{\text{opt}}N(1 + a)E_i(r)}{(N + \sum_{i=1}^{N} a_i)\overline{E}(r)}.$$

This means that the nodes with more energy will have more chances to be the cluster-heads than the nodes with less energy. Thus the energy of network is well distributed in the evolving process.

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

Where R denote the total rounds of the network lifetime. It means that every node consumes the same amount of energy in each round, which is also the target that energy-efficient algorithms should try to achieve. From Eq. (7), considering E(r) as the standard energy, DEEC controls the rotating epoch n_i of each node according to its current energy, thus controls the energy expenditure of each round.

As a result, the actual energy of each node will fluctuate around the reference energy E(r). Therefore, DEEC guarantees that all the nodes die at almost the same time. This can be shown by the simulation results of Section5. In fact, it is the main idea of

DEEC to control the energy expenditure of nodes by means of adaptive approach.

To compute E(r)by Eq.(12), the network lifetime R is needed, which is also the value in an ideal state. Assuming that all the nodes die at the same time, R is the total of rounds from the network begins to the entire nodes die. Let E round denote the energy consumed by the network in each round. R can be approximated as follow

$$R = \frac{E_{\text{total}}}{E_{\text{round}}}.$$

Estimating average energy of networks

In the analysis, we use the same energy model as proposed in [13]. In the process of transmitting an l-bit message over a distanced, the energy expended by the radio is given by:

$$E_{Tx}(l,d) = \begin{cases} lE_{\text{elec}} + l\varepsilon_{fs}d^2, & d < d_0 \\ lE_{\text{elec}} + l\varepsilon_{mp}d^4, & d \geqslant d_0 \end{cases}$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, and $\in_{fs} d^2$ or $\in_{mp} d^4$ is the amplifier energy that depends on the transmitter amplifier model.

We assume that the N nodes are distributed uniformly in an M·M region and the base station is located in the center of the field for simplicity. Each non-cluster-head send L bits data to the cluster-head a round. Thus the total energy dissipated in the network during a round is equal to:

$$E_{\text{round}} = L(2NE_{\text{elec}} + NE_{\text{DA}} + k\varepsilon_{mp}d^4_{\text{toBS}} + N\varepsilon_{fs}d^2_{\text{toCH}})$$

Where k is the number of clusters, E_{DA} is the data aggregation cost expended in the cluster-heads, d to BS is the average distance between the cluster-head and the base station, and d to CH is the average distance between the cluster members and the cluster-head. Assuming that the nodes are uniformly distributed, we can get [13, 10]:

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

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

$$k_{\text{opt}} = \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}\frac{M}{d^2_{\text{toBS}}}}.$$

We obtain the energy E_{round} dissipated during a round. Thus we can compute the lifetime R not prerequisite in practical operation of DEEC. The approximation of R_{is} enough to get the reference energy E(r), thus DEEC can adapt well to heterogeneous environments.

Initially, all the nodes need to know the total energy and lifetime of the network, which can be determined a priori.

In our DEEC protocol, the base station could broadcast the total energy E_{total} and estimate value R of lifetime to all nodes. When a new epoch begins, each node s_i will use this information to compute its average probability p_i by Eq s. (12) and (11). Node s_i will substitute pi into Eq. (6), and get the election threshold T (si), which is used to decide if node s_i should be a cluster-head in the current round.

III. Results and Discussions

The performance of the LEACH and DEEC protocols simulation results has been carried out using the NS 2 simulator. In this project simulation results are shown by varying number of nodes and speed of nodes. The simulation parameter was shown in table 3.1.

Table I: Simulation Parameters

Simulation parameter	Value
Routing Protocols	LEACH, DEEC
MAC	802.11
Simulation area	1000×1000 sq.m
Number of Nodes	50,60,70,80,90,100
Traffic Type	FTP
Simulation time	100 sec
Energy	10
Speed	5, 10, 15, 20m/sec
Antenna	Omni Directional
Propagation mode	TwoRayGround

The power analysis of routing protocols is one of the most important analyses of wireless sensor networks. Because of WSN are generally deployed in hostile areas and their nodes run on limited power supplied by batteries.

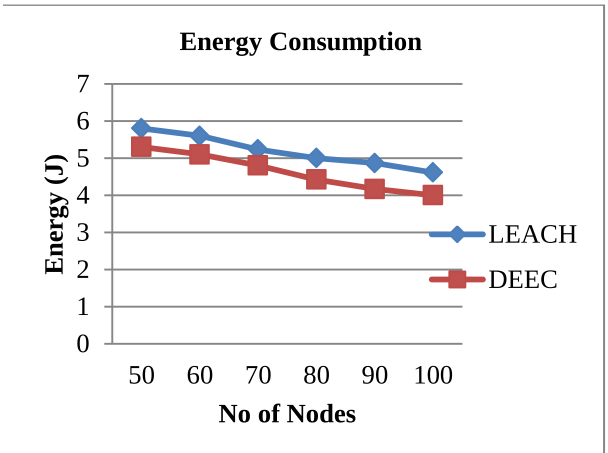

Figure 3.1: Comparison of Energy consumption with no of nodes varied

The Figure 3.1 shows the Power Consumption of LEACH and DEEC protocols for varying number of nodes. Their comparison is given by the superimposed plot shown in Figure 3.1. Observe from the graph that the Power Consumption of LEACH is much higher than DEEC. Hence DEEC is more energy efficient than LEACH protocol because of it consumes less power than LEACH protocol by varying number of nodes. The number of nodes varied from 10 nodes to 100 nodes as shown in below figure 3.1.

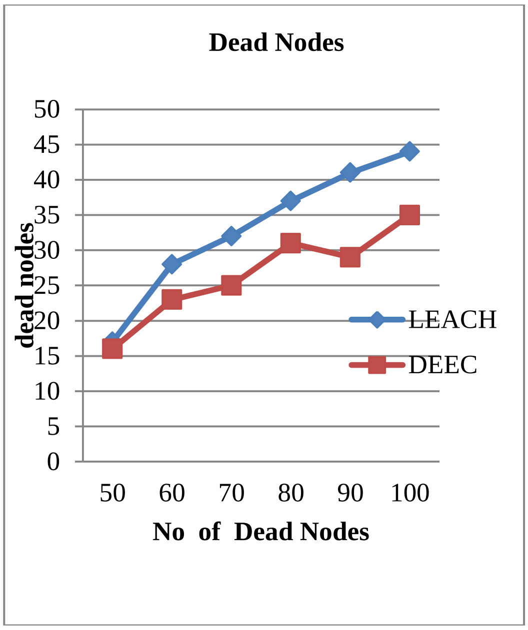

Figure 3.2: Comparison of no of dead nodes with no of nodes varied

The comparison is given by the superimposed plot shown in Figure 3.2 We observed from the graph that the number of dead nodes of DEEC is always lower than that of LEACH which makes it more desirable for increasing the network lifetime is always higher in DEEC than LEACH protocol by varied number of node in wireless sensor networks .The transmission from sensors nodes to sink node happens either between cluster node and its head or between cluster head and sink node.

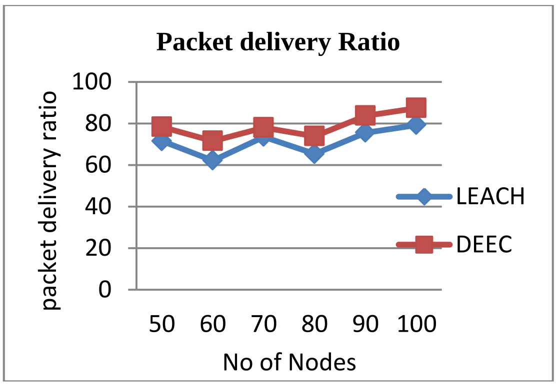

Figure 3.3: Comparison of Packet Delivery Ratio with no of nodes varied

The comparison is given by the superimposed plot shown in Figure 3.3 from the graph that the number of dead nodes of DEEC is always higher than that of LEACH. The DEEC protocol have less drop packet which shows that more desirable for increasing the network lifetime is always higher in DEEC than LEACH protocol by varied speed of the node in wireless sensor networks.

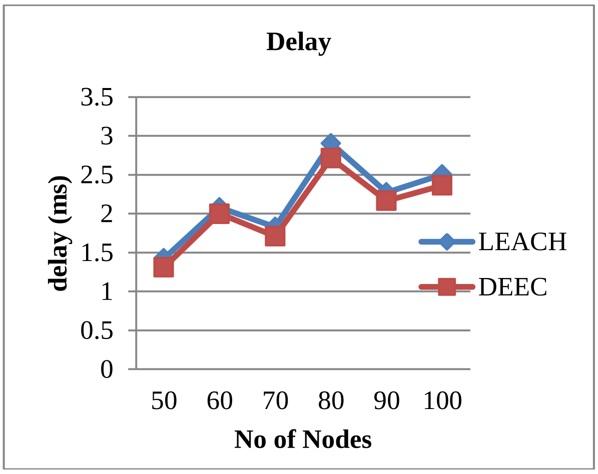

Figure 3.3: Comparison of Delay Vs no of nodes

The Figure 3.4 shows the delay of LEACH and DEEC protocols for varying no of nodes. Their comparison is given by the superimposed plot shown in Figure 3.4 Observe from the graph LEACH is higher delay than DEEC. Hence DEEC is more efficient than LEACH protocol.

CONCLUSIONS

In this paper, DEEC protocol a modification of the LEACH protocol to further increase life time of the network by efficient clustering method. DEEC protocol deals with the network as a number of clusters while introducing an efficient mechanism for communications among nodes. DEEC protocol increases the stable period of the sensor network by assigning a multi level energy to the sensors. DEEC is compared with the LEACH protocol by using performance parameters, Energy consumption and Dead node with respect to number of nodes variation. About 8-9% improvement in energy consumption, 10-11% improvement in dead nodes has been achieved by using DEEC protocol when compared to LEACH protocol.

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