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Enhanced Distributed Energy Efficient Clustering (E-DEEC) based on Particle Swarm Optimization

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Abstract— **In this paper, we test Distributed Energy-Efficient Clustering (DEEC), Developed DEEC (DDEEC) and Enhanced DEEC (EDEEC) with PSO under several different scenarios containing high level heterogeneity to low level heterogeneity. In order to conclude the behaviour of this heterogeneous protocols.**

Keywords- **DCCC, DDEEC, EDEEC PSO.**

I. Introduction

Routing in Wireless Sensor Networks (WSNs) [1] has been the subject of intense research efforts for years. As the battery, capability of computing, storage and data processing of a sensor are limited, how to reduce the energy consumption while prolonging the network lifetime stays the key problem.

Clustering is widely adopted in WSNs, where the entire network is divided into multiple clusters. Clusters have cluster heads (CHs) be responsible for data aggregation. It has the advantages of low energy consumption, simple routing scheme and good scalability, and it reduce the energy hole problem to some extent. Most traditional clustering routing protocols for WSN are based on homogeneous networks where all sensor nodes are identical in terms of battery energy and hardware configuration. However, due to the variation of nodes' resources and possible topology change of the network, heterogeneous senor networks [2] are more practical in reality. The presence of heterogeneous nodes with enhanced capacity is known to increase network reliability and lifetime. [3]

Technological developments in the field of Micro Electro Mechanical Sensors (MEMS) have enabled the development to tiny, low power, low cost sensors having limited processing, wireless communication and energy resource capabilities. With the passage of time researchers have found new applications of WSN. In many critical applications WSNs are very useful such as military surveillance, environmental, traffic, temperature, pressure, vibration monitoring and disaster areas. To achieve fault tolerance, WSN consists of hundreds or even thousands of sensors randomly deployed inside the area of interest [4].

All the nodes have to send their data towards BS often called as sink. Usually nodes in WSN are power constrained due to limited battery, it is also not possible to recharge or replace battery of already deployed nodes and nodes might be placed where they cannot be accessed. Nodes may be present far away from BS so direct communication is not feasible due to limited battery as direct communication requires high energy. Clustering is the key technique for decreasing battery consumption in which members of the cluster select a Cluster Head (CH). Many clustering protocols are designed in this regard [5, 6]. All the nodes belonging to cluster send their data to CH, where, CH aggregates data and sends the aggregated data to BS [7-9]. Under aggregation, fewer messages are sent to BS and only few nodes have to transmit over large distance, so high energy is saved and over all lifetime of the network is prolonged. Energy consumption for aggregation of data is much less as compared to energy used in data transmission. Clustering can be done in two types of networks i.e. homogenous and heterogeneous networks. Nodes having same energy level are called homogenous network and nodes having different energy levels called heterogeneous network. Low-Energy Adaptive Clustering Hierarchy (LEACH) [8], Power Efficient Gathering in Sensor Information Systems (PEGASIS) [10], Hybrid Energy-Efficient Distributed clustering (HEED) [11] are algorithms designed for homogenous WSN under consideration so these protocols do not work efficiently under heterogeneous scenarios because these algorithms are unable to treat nodes differently in terms of their energy. Whereas, Stable Election Protocol (SEP) [12], Distributed Energy-Efficient Clustering (DEEC) [13], Developed DEEC (DDEEC) [14], Enhanced DEEC (EDEEC) [15] and Threshold DEEC (TDEEC) [16] are algorithms designed for heterogeneous WSN. SEP is designed for

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two level heterogeneous networks, so it cannot work efficiently in three or multilevel heterogeneous network. SEP considers only normal and advanced nodes where normal nodes have low energy level and advanced nodes have high energy. DEEC, DDEEC, EDEEC and TDEEC are designed for multilevel heterogeneous networks and can also perform efficiently in two level heterogeneous scenarios.

DEEC

Let $p_i = 1/n_i$, which can be also regarded as the 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 p_i 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 the nodes have different amounts of energy, pi of the nodes with more energy should be larger than p_{opt}. Let $\bar{E}(r)$ denote the average energy at round r of the network, which can be obtained by

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

The probability of the nodes of nodes will be given by:

$$\sum_{i=1}^{N} P_i = \sum_{i=1}^{N} P_{opt}\frac{E_i(r)}{\bar{E}(r)} = \sum_{i=1}^{N}\frac{E_i(r)}{\bar{E}(r)} = Np_{opt}$$

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

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

Where, G is the set of nodes that are eligible to be cluster head sat round r. If node s_i has not been a cluster-head during the most recent n_i rounds, we have s_i 2 G. In each round r, when node s_i 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.

DDEEC

$$TH_{REV} = E_0\left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}}\right)$$

Threshold residual energy T h is given as in [14] and given below:

$$TH_{REV} \simeq (7/10)E_0$$

Average probability pi for CH selection used in DDEEC is as follows as in [14]:

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & for\ Nml\ nodes, E_i(r) > TH_{REV} \\ \dfrac{p_{opt}E_i(r)(1+a)}{(1+am)\bar{E}(r)} & for\ adv\ node, E_i(r) > TH_{REV} \\ C\dfrac{p_{opt}E_i(r)(1+a)}{(1+am)^{\sim}\bar{E}(r)} & for\ adv\ node, ml\ nodes\ E_i(r) \le TH_{REV} \end{cases}$$

EDEEC-PSO

EDEEC uses concept of three level heterogeneous network as described above. It contains three types of nodes normal, advanced and super nodes based on initial energy. p_i is probability used for CH selection and p_{opt} is reference for p_i. EDEEC uses different p_{opt} values for normal, advanced and super nodes, so, value of pi in EDEEC is as follows:

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ s_i\ is\ the\ normal\ node \\ \dfrac{p_{opt}(1+a)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ s_i\ is\ the\ advanced\ node \\ \dfrac{p_{opt}(1+b)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ s_i\ is\ the\ super\ node \end{cases}$$

Threshold for CH selection for all three types of node is as follows

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$$T(s_i) = \begin{cases} \dfrac{p_i}{1 - p_i\left(r \bmod \dfrac{1}{p_i}\right)} & \text{if } p_i \in G' \\ \dfrac{p_i}{1 - p_i\left(r \bmod \dfrac{1}{p_i}\right)} & \text{if } p_i \in G'' \\ \dfrac{p_i}{1 - p_i\left(r \bmod \dfrac{1}{p_i}\right)} & \text{if } p_i \in G''' \\ 0 & \text{otherwise} \end{cases}$$

A. PSO

The PSO procedure has various phases consist of Initialization, Evaluation, Update Velocity and Update Position.

$$v_1(t) = \underbrace{w\overline{v_l(t-1)}}_{inertia} + \underbrace{c_1 r_1\left(x_1^{\#}(t-1) - \overline{x_l(t-1)}\right)}_{Personalinfluence} + \underbrace{c_2 r_2\left(x^*(t-1) - \overline{x_l(t-1)}\right)}_{Socialinfluence}$$

Where

$\overline{x_l(t)}$ = The position-vector in iteration t

i = The index of the particle

$\overline{v_l(t)}$ = The velocity- vector in iteration t

$x_1^{\#}(t)$ = The position so for of particle i in iteration t and its j^{th} dimensional value is $x_{ij}^{\#}(t)$.

The best position vector among the swarm here to force is then stored in a vector $x^*(t)$ and its j^{th} dimensional value is $x_{ij}^*(t)$.

r_1, r_2 = random numbers in the interval [0, 1].

c_1, c_2 = positive constants and

w is called the inertia factor.

$$\overline{x_l(t)} = \overline{x_l(t-1)} + \overline{v_l(t)}$$

II. SIMULATION RESULTS

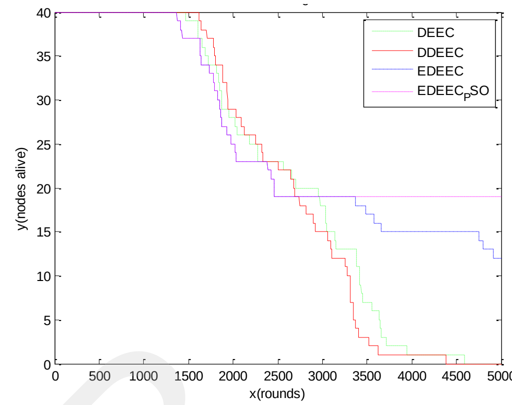

Figure 1: Alive nodes comparison

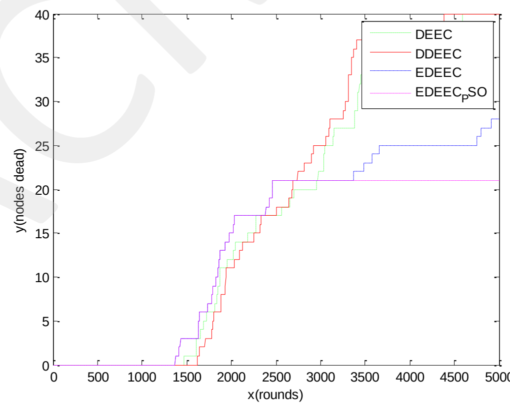

Figure 2: Dead nodes comparison

III. CONCLUSION

We have examined DEEC, E-DEEC with PSO, and DDEEC for heterogeneous WSNs containing different level of heterogeneity. Simulations prove that DEEC and DDEEC perform well in the networks containing high energy difference between normal, advanced and super nodes. Whereas, we find out that EDEEC-PSO perform well in all scenarios. EDEEC-PSO has best performance in terms of stability period and life time.

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