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Comparative Analysis of LEACH, DEEC and DDEEC

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Abstract – **This paper is based on wireless sensor networks, in conjunction with an appropriate management methodology that allows us to analyze and verify the behaviour of these wireless networks. To make WSN energy efficient and to increase the lifetime of the network, this research work presents Distributed Energy-Efficient Clustering (DEEC), Developed DEEC (DDEEC) and Low-Energy Adaptive Clustering Hierarchy (LEACH). Performance of this approach is evaluated using certain evaluation parameters; Throughput and Network Lifetime.**

Keywords – **BS, CH, DEEC, DDEEC, LEACH, WSN.**

I. Introduction

WSN consist of large number of sensor nodes that are deployed in the environment and are powered by battery and replacing the battery of each and every node in the sensor network is impractical so it is necessary to make use of this limited energy efficiently therefore an energy efficient algorithm has to be designed. The nodes in the WSN are distributed spatially and to send the sensed data to the base station or sink node needs multi-hop communication when the base station or sink is not in range so the number of intermediate nodes are required to send this sensed data to the desired destination which consumes more energy of the network because all the intermediate nodes forward the data coming from their neighbour and to do this job they consume energy and this motivate us to reduce the number of hops and intermediate nodes taking part in transmission of data by using clustering algorithm in which the nodes are grouped into clusters and each node in cluster send data only to their concerned cluster head which is then aggregate all the data coming from the member nodes and send it to the sink or base station [1].

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 [1].

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 [2, 3]. All the nodes belonging to cluster send their data to CH, where, CH aggregates data and sends the aggregated data to BS [4] [5] [6]. 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) [5], Power Efficient Gathering in Sensor Information Systems (PEGASIS) [7], Hybrid Energy-Efficient

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Distributed clustering (HEED) [8] 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) [9], Distributed Energy-Efficient Clustering (DEEC) [10], Developed DEEC (DDEEC) [11], Enhanced DEEC (EDEEC) [12] and Threshold DEEC (TDEEC) [13] are algorithms designed for heterogeneous WSN. SEP is designed for 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.

This paper develops a WSN framework for an investigational comparison among LEACH, DEEC and DDEEC. Rest of paper is organized as follows. Section 2 presents the proposed methodology followed by the simulation and results in section 3 and finally the conclusion and future aspects are detailed in section 4.

II. Proposed Method

A. Low-Energy Adaptive Clustering Hierarchy (LEACH)

During the configuration phase, randomly generated cluster head, the random number is selected in a range between 0 and 1 in each sensor node, if the selected number is smaller than some threshold $T(n)$, then the node is selected as the head of the cluster. Formulas of $T(n)$ as follows [14]:

$$T(n) - \int_0^n \frac{p}{1-p\left[r \bmod \left(\frac{1}{p}\right)\right]} \text{ with } n \in G \qquad (1)$$

Where, p is the percentage of the number of cluster headers and the total number of nodes in the network, r is the number of the current round, G is the set of cluster nodes except the cluster head of the last rounds $\frac{1}{p}$.

B. DEEC Protocol

Distributed Energy Efficient Clustering (DEEC) is a type of key method that is used to decrease energy feeding. It can increase the scalability and lifetime of the network. In DEEC, the cluster-heads are chosen by a chance based on the ratio between remaining energy of all nodes and the average energy of the network.

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, p_i 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

$$\bar{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \qquad (2)$$

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

$$\sum_{i=1}^{N} P_i = \sum_{i=1}^{N} P_{opt}\frac{E_i(r)}{\bar{E}(r)} = \sum_{i=1}^{N}\frac{E_i(r)}{\bar{E}(r)} = Np_{opt} \qquad (3)$$

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:

$$T(S_i) = \begin{cases} \frac{p_i}{1-p_i(r \bmod \frac{1}{p_i})} & if\ s \in G \\ 0 & otherwise \end{cases} \qquad (4)$$

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_i2G. 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.

1) Coping with Heterogeneous Nodes

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 below equations for normal and advanced nodes [11].

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

Therefore p_i changes to:

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

Thus the threshold is correlated with the initial energy and residual energy of each node directly.

2) Average Energy Estimation of Network

In an ideal situation, the energy of the network and nodes are uniformly distributed, and all the nodes die at the same time. Thus estimated average energy $\bar{E}(r)$ of rth round is as follow:

$$\bar{E}(r) = \frac{1}{N}E_{Total}\left(1 - \frac{r}{R}\right) \qquad (7)$$

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Where, R denotes 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 [10].

C. DDEEC

DDEEC uses same method for estimation of average energy in the network and CH selection algorithm based on residual energy as implemented in DEEC. Difference between DDEEC and DEEC is centered in expression that defines probability for normal and advanced nodes to be a CH [11] as given in equation (6).

We find that nodes with more residual energy at round r are more probable to become CH, so, in this way nodes having higher energy values or advanced nodes will become CH more often as compared to the nodes with lower energy or normal nodes. A point comes in a network where advanced nodes having same residual energy like normal nodes. Although, after this point DEEC continues to punish the advanced nodes so this is not optimal way for energy distribution because by doing so, advanced nodes are continuously a CH and they die more quickly than normal nodes. To avoid this unbalanced case, DDEEC makes some changes in equation (6) to save advanced nodes from being punished over and again. DEEC introduces threshold residual energy as in [11] and given below:

$$TH_{REV} = E_0\left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disAN}}\right) \quad (8)$$

When energy level of advanced and normal nodes falls down to the limit of threshold residual energy then both type of nodes use same probability to become cluster head. Therefore, CH selection is balanced and more efficient. Threshold residual energy TH is given below [11]:

$$TH_{REV} \simeq (7/10)E_0 \quad (9)$$

Average probability p_i for CH selection used in DDEEC is as follows as in [11]:

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

(10)

III. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

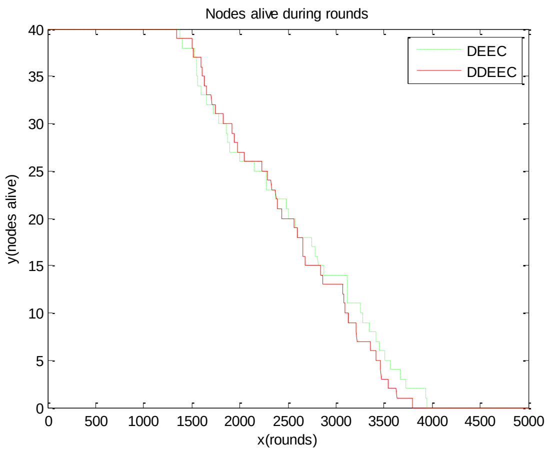

Figure 1: Alive nodes comparison for DEEC and DDEEC

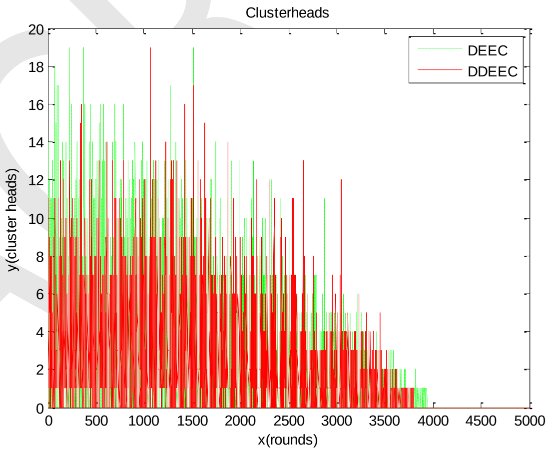

Figure 2: Cluster heads formation comparison for DEEC and DDEEC

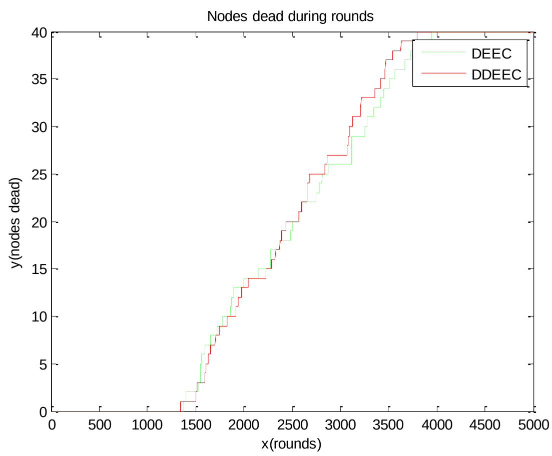

Figure 3: Dead nodes comparison for DEEC and DDEEC

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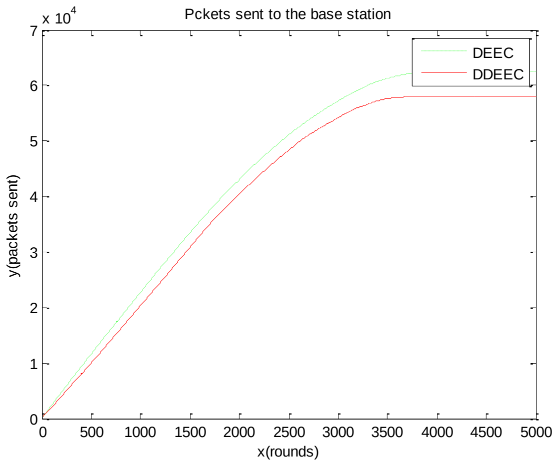

Figure 4: Comparison of packets sent to the base station for DEEC and DDEEC

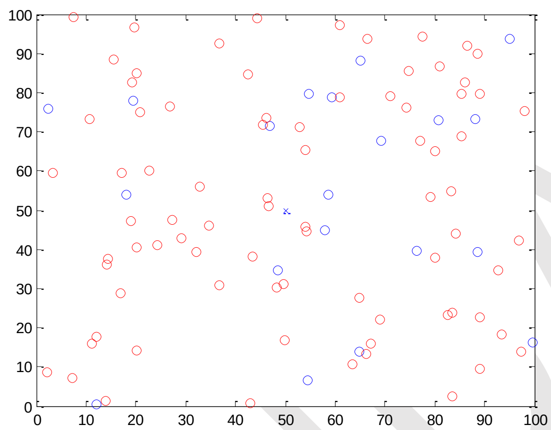

Figure 5: Cluster head formation in LEACH

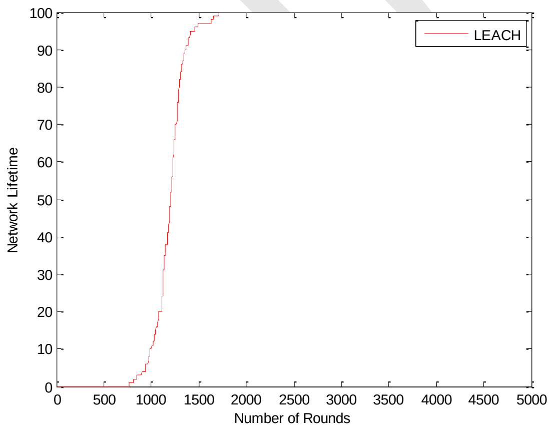

Figure 6: Network lifetime in LEACH

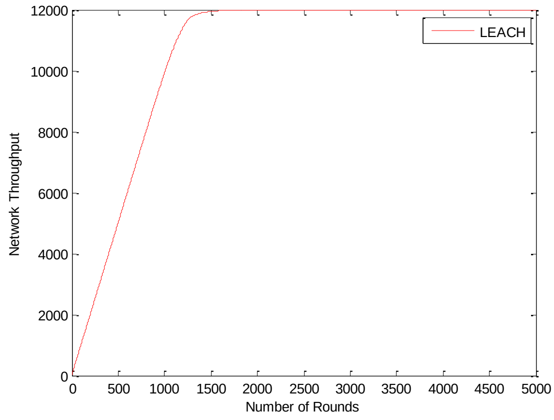

Figure 7: Network throughput in LEACH

IV. CONCLUSION

In this paper we have examined the current state of proposed clustering protocols, specifically with respect to their power and reliability requirements. In wireless sensor networks, the energy limitations of nodes play a crucial role in designing any protocol for implementation. In addition, Quality of Service metrics such as delay, data loss tolerance, and network lifetime expose reliability issues when designing recovery mechanisms for clustering schemes. These important characteristics are often opposed, as one often has a negative impact on the other.

We have examined DEEC, DDEEC and LEACH 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 DEEC perform well in all scenarios. It has best performance in terms of stability period and life time.

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