Comparative Analysis of EDDEEC & Fuzzy Cost Based EDDEEC Protocol for WSNs

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***Abstract*—This research paper has focused on evaluating the performance of the heterogeneous WSNs using fuzzy based cluster head selection and the tradition EDDEEC protocols. The EDDEEC has used different probability function for choosing the best cluster head by using the remaining energy and average energy of the network. But EDDEEC has neglected the use of number of neighbours of sensor nodes during cluster head selection. Whereas fuzzy based EDDEEC heterogeneous protocol is based on the concept of thee fuzzy cost. The fuzzy cost is dynamic in nature and evaluated on the basis of the remaining energy and the node centrality. MATLAB simulation tool is considered in this paper. The comparative analysis has shown that the fuzzy cost based EDDEEC outperforms over the existing EDDEEC protocol.**

Keywords: Network Lifetime, Stable Period, Clustering, DEEC, Fuzzy Cost

I. Introduction

Wireless sensor networks (WSNs) [1] are among the widely used types of ad-hoc wireless networks. Main objective of WSNs is to classify, collect, and development of the information within a monitoring area. In 1980's DARPA i.e., Defence Advanced Research Projects Agency started a program named Distributed Sensor Networks (DSN) from which further WSN was formed. WSN consists of more than hundreds of little sensor nodes which have restricted power, memory and computational capability. These node route data and throw it base station called as sink. For communication of data among nodes and sink many routing technology are used firstly, such as direct communication and multi-hop data communication [3]. But due to restricted battery life of nodes this techniques were not so useful because early loss of some node in both techniques were be unsuccessful to acquire in the network appropriateness periods. The purpose of the WSN involves many fields such as the armed field; reforest fire finding, earthquake detection, air pollution structure monitor and other intense environments. The sensor nodes in WSN have restricted power, memory and computational capability. A sensor node makes use of its communicating mechanism in order to transmit the data, over a wireless channel, to a base station (sink). WSNs accept energy-constrained battery-powered devices. The sensor nodes are abounding by non-rechargeable batteries mount on sensors, therefore minimize energy utilization in order to expand the existence of network is an important issue in WSNs [8]. Since the major portion of energy utilization in sensor nodes is due to communication, variety of a capable algorithm considerably reduces the communication energy. By clustering of sensor nodes into some groups called clusters, sensor nodes of each cluster send their data to definite sensor nodes in the cluster called Cluster Heads (CHs). Then, CH nodes spread gathered information to the Base Station (BS). A sensor network design is affected by many factors [9], which include scalability, fault tolerance, sensor network topology, production costs, transmission media, operating environment, hardware constraints, and power consumption. These factors are important because they provide guideline to an algorithm or design various routing protocol [10] to improve the network lifetime of WSNs.

II. Various Clustering Techniques

A. Leach

Low Energy Adaptive Clustering Hierarchy i.e., LEACH [4] is the first hierarchical cluster-based routing set of rules for wireless sensor network. In LEACH, the nodes classify themselves into local clusters. A dedicated node preferred as cluster-head is dependable for designing and employing a TDMA (Time Division Multiple Access) plan and aggregating the data coming from different nodes and sending it to the BS [6]. The process of LEACH is divided into round. In this protocol each round has two phases: Set-up Phase and Steady-state Phase.

B. Teen

The main features of Threshold sensitive energy efficient sensor network [5] protocol are that the sensor nodes have to send out to their CH to consume fewer energy, extra data processing is done only by CH to reduce energy consumption, CHs deployed at higher levels of hierarchy transmit the data which use more energy. To remove this issue, all nodes are given the opportunity to be CH for a time period T (cluster Period). In TEEN, nodes sense the network all the time and data broadcasting is done only when there is an extensive change in the sensed data. HT is the absolute value of an attribute to trigger on its transmitter and report to its respective CH. HT allows nodes to broadcast data, if the data occurs in the range of interest. Therefore, a considerable reduction of the transmission delay occurs. Moreover, ST is the small change in the value of the sensed attribute. Next transmission takes place when there is a small change in the sensed attribute once it arrives at the HT. So, it further decreases the number of transmissions [7].

C. DDEEC

Developed Distributed Energy Efficient Clustering (DDEEC) [13] protocol uses same way for judgment of usual energy in the network and CH collection algorithm based on remaining energy as deployed in DEEC [11]. Difference between DDEEC and DEEC is centred in phrase that defines probability for a normal and an advanced node to become a CH.

It is found that nodes with more remaining energy at round r are more likely to become CH, in these way nodes having advanced energy principles or advanced nodes will become CH more number of times as compared to the nodes with low energy. After some time in a sensor network there comes a point where there are advanced nodes having same remaining energy level like normal nodes energy level are present in the network, still after this point also DEEC continues to penalize the advanced nodes. So this is not the best way to allocate the energy as advanced nodes are constantly becoming CH and due to this they die early than the normal nodes. SEP [16] is used only for two level heterogeneous sensor network. To avoid this uneven case, DDEEC makes some changes to keep away advanced nodes from being punished over and again. It introduced Threshold residual energy [13] in which all type of nodes has same chance to become CHs for current round.

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

D. EDEEC

Enhanced Distributed Energy Efficient Clustering (EDEEC) [14] used perception of three stage heterogeneous network. It contains three types of nodes normal, advanced and super nodes based on original energy. p_i is the possibility used for CH collection and p_{opt} is indication for p_i.

$$p_i = \frac{p_{optE_{i(r)}}}{1+m(a+m_{0b)E(r)}} \text{ if } \mathrm{s_i} \text{ is the normal node} \quad (2)$$

$$p_i = \frac{p_{opt(1+a)E_{i(r)}}}{1+m(a+m_{0b)E(r)}} \text{ if } \mathrm{s_i} \text{ is the advanced node} \quad (3)$$

$$pi = \frac{p_{opt(1+b)E_{i(r)}}}{1+m(a+m_{0b)E(r)}} \text{ if } \mathrm{s_i} \text{ is the super node} \quad (4)$$

E. TDEEC

Threshold Distributed Energy Efficient Clustering (TDEEC) [17] uses similar method for CH choice and usual energy evaluation as proposed in DEEC. At each about nodes has been decided whether it can become a CH or not by choosing an arbitrary number between 0 and 1. If number is less than threshold then nodes choose to become a CH for the given round. In TDEEC, threshold value is used to and based upon that rate a node decides whether to become a CH or not by introducing remaining energy and average energy of that round with respect to best possible no of nodes.

F. EDDEEC

Enhanced Developed Distributed Energy Efficient Clustering (EDDEEC) [2] method is used for heterogeneous WSNs. It is three level heterogeneous WSNs. It uses same scheme for CH choice based on initial, remaining energy level of the nodes, radio dissipation and average energy of network as in DEEC. At beginning of the round, each node makes a decision whether to become a CH or not for current round based on Threshold. heterogeneous Wireless sensor network have more than two types of nodes so in EDDEEC three level heterogeneity are used which contain normal, advance and super nodes and uses same probabilities of three types of nodes as described in EDEEC [14]. In EDEEC after some rounds, some super and advance nodes have same remaining energy level as normal nodes due to continually CH selection. Therefore it continues to penalize advance and super sensor nodes for CH choice. Same issue with DEEC, it also continues to penalize just advance nodes and DDEEC is limited only for two-level heterogeneous networks. To eliminate this unbalanced problem in three-level heterogeneous WSNs EDDEEC changes in function which illustrated in EDEEC for calculating probabilities of normal, advance and super nodes. These modifications are based on absolute remaining energy level $\mathrm{T_{absolute}}$, that is the value in which advance and super sensor nodes have similar energy level as in case of normal nodes. Using $\mathrm{T_{absolute}}$ all kinds of nodes has identical probability for CH selection.

$$\frac{\mathrm{P_{opt}E_i(r)}}{(1+\mathrm{m(a+m_ob)})\bar{\mathrm{E}}(\mathrm{r})}$$
for normal nodes if $\mathrm{E_i(r) > T_{absolute}}$, (5)

$$\frac{\mathrm{P_{opt}(1+a)E_i(r)}}{(1+\mathrm{m(a+m_ob)})\bar{\mathrm{E}}(\mathrm{r})}$$
for advance node if $\mathrm{E_i(r) > T_{absolute}}$, (6)

$$\frac{\mathrm{P_{opt}(1+b)E_i(r)}}{(1+\mathrm{m(a+m_ob)})\bar{\mathrm{E}}(\mathrm{r})}$$
for super nodes if $\mathrm{E_i(r) > T_{absolute}}$, (7)

$$c\,\frac{\mathrm{P_{opt}(1+b)E_i(r)}}{(1+\mathrm{m(a+m_ob)})\bar{\mathrm{E}}(\mathrm{r})} \text{ Otherwise} \quad (8)$$

Here $\bar{\mathrm{E}}(r)$ is average energy at round r of the network, $\mathrm{E_i(r)}$ is residual energy at round r, m is fraction between node heterogeneity, P_{opt} is probability of optimum number of cluster head, a, b is boost a power for advance and super nodes.

III. Fuzzy Based EDDEEC

Step 1: Initialize the WSNs with required parameters like nodes position, sink position, initial energy of each kind of nodes etc.

Step 2: for every node i repeat the following steps until all nodes become dead.

Step 3: Select cluster head using following equations i.e. normal (eq. 9), advance (eq. 10), super nodes (eq. 11) and for all types of nodes having same remaining energy (eq. 12).

$$\frac{P_{opt}E_i(r)}{(1+m(a+m_o b))\bar{E}(r)} * \text{Fuzzy\_cost for normal nodes if } E_i(r) > T_{absolute} \quad (9)$$

$$\frac{P_{opt}(1+a)E_i(r)}{(1+m(a+m_o b))\bar{E}(r)} * \text{Fuzzy\_cost for advance node if } E_i(r) > T_{absolute} \quad (10)$$

$$\frac{P_{opt}(1+b)(r)}{(1+m(a+m_o b))\bar{E}(r)} * \text{Fuzzy\_cost for super nodes if } E_i(r) > T_{absolute} \quad (11)$$

$$c\frac{P_{opt}(1+b)E_i(r)}{(1+m(a+m_o b))\bar{E}(r)} * \text{Fuzzy\_cost for nor, adv, sup nodes if } E_i(r) \leq T_{absolute} \quad (12)$$

Where Fuzzy cost will be evaluated using the Algorithm 1.

Step 4: Evaluate the energy dissipation and update the remaining energies it. Where distance will be evaluated using eq. 5 and updating of energy will be based upon the eq. 6 and eq. 7.

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}}, \; d_{toBS} = 0.765\frac{M}{2} \quad (13)$$

$$E_{Tx}(l, d) = l E_{elec} + l\varepsilon_{fs}d^2, \; d < d_0 \quad (14)$$

$$E_{Tx}(l, d) = l E_{elec} + l\varepsilon_{mp}d^4, \; d \geq d_0 \quad (15)$$

Algorithm 1: Fuzzy Cost Calculation

I. Initial Round:

1. Sink selects cluster head according to the weighted probability function (Padv for advance nodes, Psup for super nodes, Pnrm for normal nodes) and broadcast the CH_message.
2. Cluster formation will be done and data transform will be take place.
3. Each sensor node computes the remaining energy and sensor node centrality and sends the values to sink through Cluster Head.
4. End

II. General Rounds:

1. Fuzzy cost will be calculated by Sink using remaining energy and sensor node centrality.
2. Sink chooses the Cluster Head based on the value of fuzzy cost and broadcast the CH_message.
3. Cluster formation will be done and data transform will be take place.
4. Each sensor node computes the sensor node centrality and remaining energy and sends the values to sink through Cluster Head.
5. End

IV. Experimental Setup

This section contains the experimental setup which has been used in this research paper. Table 1 has shown various constants and variables required to simulate this work. These parameters are standard values used as benchmark for WSNs.

Table 1 Experimental Setup

Parameter	Value
Area (x,y)	100,100
Base Station (x,y)	50,50
Nodes (n)	100
Probability (p)	0.1
Initial Energy (Eo)	0.1
Transmiter_Energy	50 nJ/bit
Receiver_Energy	50 nJ/bit
Free space (Amplifier)	10 nj/bit/m^2
Multipath (Amplifier)	0.0013 pJ/bit/m^4
A (Energy Factor Between Normal and Super Nodes)	3
B (Energy Factor Between Normal and Advance Nodes)	2
Maximum Lifetime	5000
Message Size	4000 bits
M (Fraction of Advanced Nodes)	0.3
X (Fraction of Super Nodes)	0.3
Effective Data Aggregation	5 nJ/bit/signal

V. Experimental Results

On applying fuzzy cost functions, following results will be achieved using MATLAB tool.

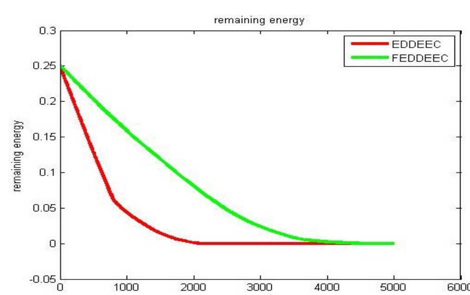

Fig. 1 Remaining Energy

Figure 1 is showing the comparative analysis of remaining energy. X-axis is representing the energy in joules. It has been clearly shown that the remaining energy in cased of FEDDEEC is quite more than that of the EDDEEC. Thus FEDDEEC outperforms over the EDDEEC with respect to remaining energy.

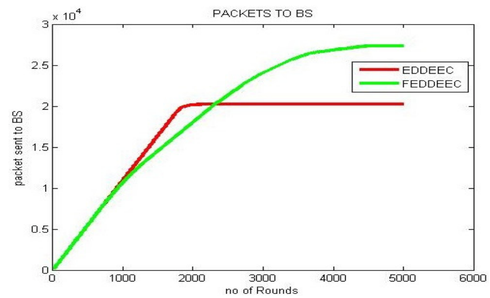

Fig. 2 Total Number of Packets Sent to Base Station

Figure 2 is showing the comparison of FEDDEEC and the EDDEEC with respect to total number of packet sent to base station. X-axis is representing packet sent to base station. Y-axis is representing number of rounds. It has been clearly shown that the overall packers sent to base station in case of FEDDEEC are quite more than that of the EDDEEC. Thus FEDDEEC outperforms over the EDDEEC with respect to packets sent to base station.

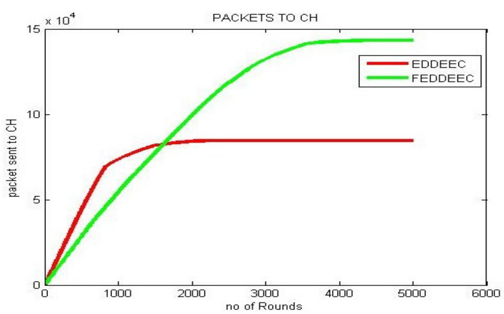

Fig. 3 Total Number of Packets Sent to Cluster Head

Figure 3 is showing total number of packet sent to cluster head. It has been evidently shown that the overall packers sent to cluster head in instance of FEDDEEC are fairly supplementary than that of the EDDEEC. Thus FEEDDEEC overtakes over the EDDEEC with respect to packets sent to cluster head.

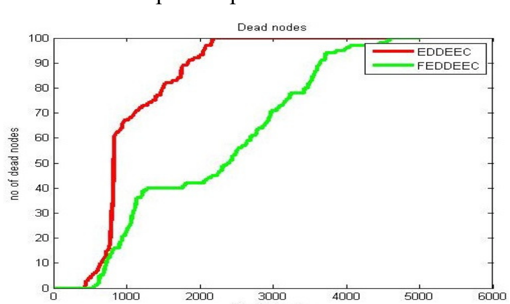

Fig. 4 Total Number of Dead Nodes

Figure 4 is showing total number of dead nodes during the network lifetime. It is showing all nodes die at 2172 and 4601 round respectively. Thus FEDDEEC overtakes over the EDDEEC with respect to dead nodes. This figure has shown that Fuzzy based EDDEEC increased the network lifetime.

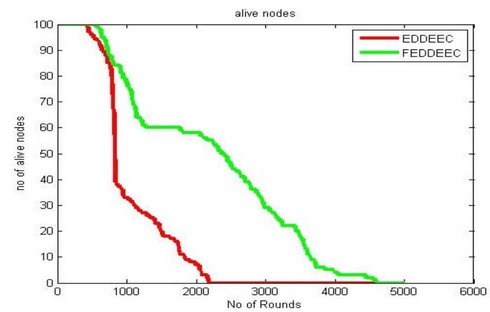

Fig. 5 Stability Period

Figure 5 is showing the stability period of the nodes. It is showing that the first node for EDDEEC and FEDDEEC dies at 423 and 517 round, respectively. This figure has shown that Fuzzy based EDDEEC increased the stability period.

TABLE 2 COMPARATIVE ANALYSIS

Protocols	First Node Dead	Last Node Dead
EDDEEC	423	2172
FEDDEEC	517	4601

Table 2 has shown the comparison between EDDEEC and FEDDEEC with respect to first node dead and last node dead time.

VI. CONCLUSION

This paper has focused on the performance analysis of EDDEEC and fuzzy cost based EDDEEC. The FEDDEEC is based on fuzzy cost and has the ability to overcome the limitation of the EDDEEC by optimized dividing the sensor field among consistent number of clusters. Due to the limitation of the real time environment this work has done simulation in the well-known MATLAB tool. The comparative analysis has shown that the due to the fuzzy based optimization in the FEDDEEC it significantly improve the results than that of existing EDDEEC in terms of packet sent to base station, network lifetime and stability period. In near future we will justify the proposed algorithm further by using the mobile sink and also by placing the sink statically in and outside the sensor field.

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