Optimizing the Cluster Partition Using Tabsolute and Fuzzy cost for Heterogeneous WSNs

Baljinder Kaur¹, Parveen Kakkar²
¹Dept. of CSE, DAV Institute of Engineering & Technology, Punjab, India
bkkhinda@gmail.com
²Dept. of CSE, DAV Institute of Engineering & Technology, Punjab, India
Parveen.daviet@gmail.com

Abstract

Due to limited battery of sensor nodes, so energy efficiency found to be main constraint of limited life of WSNs. Therefore the main focus of the present work is to find the ways to minimize the energy consumption problem and how one can enhance the network stability period and life time. Many researchers have proposed different kind of the protocols to enhance the network lifetime but still much improvement can be done further to enhance the network lifetime further. This research paper has focused on improve the performance of the heterogeneous WSNs using fuzzy based cluster head selection. 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 neighbors of sensor nodes during cluster head selection. So this work has proposed new Tabsolute and fuzzy based heterogeneous protocol. The fuzzy cost will be evaluated on the basis of the remaining energy and the node centrality. The fuzzy cost will be dynamic in nature as it is evaluated in each round. The comparative analysis has shown the improvement of the proposed protocol over others.

Keywords: WSNs, NETWORK LIFETIME, STABLE PERIOD, CLUSTERING, LEACH, DEEC, FUZZY COST.

1. Introduction

Wireless Sensor Networks (WSNs) are networks that consist of nodes also called sensors which are deployed in a region. These sensors work with each other to sense various types of physical information from the atmosphere. In various significant fields WSNs are very helpful like environmental traffic, military surveillance, area monitoring, air pollution monitoring, wastewater monitoring, pressure etc [1] [9]. Current WSNs is working on the problems of low-power communication, computation and energy storage.

All sensor nodes process data and transmit it to base station also called sink. In WSNs nodes are battery constrained due to limited energy [2] [3] [4]. So use of the battery in efficient way becomes critical issue. A number of protocols play an important role to reduce energy consumption. Direct communication and multi-hop data transmission used initially. But due to limited power of sensor nodes these techniques don’t work effectively. Energy is very critical issue in WSN, because of limited energy in sensor nodes, so to conserve energy clustering technique was introduced; in which out of thousands of nodes few nodes become cluster head and they manage the entire network.

Cluster head is a node which is responsible for maintain cluster, collect data from nodes in the cluster and communicating with sink. By using clustering methodology it has been observed that there is large amount of energy that has been saved. In static clustering method some rules were followed to elect a cluster head, once a cluster is formed and cluster head is elected, the cluster was statically operated until the head node dead.

Because cluster head node have more responsibility so rapid decrease in energy in the Cluster head node. The death time was head node was too early in static clustering technique. So there was a need required the Wenzimen proposed a protocol based on adaptive clustering technique he named it LEACH.

2. Clustering

Clustering [2] [4] [6] [9] is a technique where nodes are arranged into clusters that are useful in achieving energy efficiency. All nodes belonging to the same cluster send their data to cluster head. The main
function of cluster head is to provide efficiently data communication between sensor nodes and the base station. So the cluster head should have high energy as compared to other nodes. CH aggregates data and sends aggregated data to BS where the end-user can access the data.

3. Different Clustering Schemes

In Wireless sensor network clustering can be done in two types of network i.e. homogeneous and heterogeneous.

All sensor nodes with identical energy level are known as homogeneous WSNs. Low-Energy Adaptive Clustering Hierarchy (LEACH) [4], Threshold sensitive energy efficient sensor network protocol (TEEN) [5], LEACH-centralized (LEACH-c) [6], Adaptive threshold sensitive energy efficient sensor network protocol (APTEEN) [7], Power Efficient Gathering in Sensor Information Systems (PEGASIS) [8], Hybrid Energy-Efficient Distributed Clustering (HEED) [9] protocols are widely used for homogeneous WSNs.

In heterogeneous WSNs all sensor nodes have dissimilar energy level and fewer energy nodes died first than the high energy sensor nodes. Stable Election Protocol (SEP) [10], Distributed Energy Efficient Clustering (DEEC) [11], Developed DEEC (DDEEC) [15] and Enhanced DEEC (EDDEEC) [16] are well known heterogeneous WSNs protocols. Low-Energy Adaptive Clustering Hierarchy (LEACH) [4] used for homogeneous protocol in which all the nodes have same energy level. There are number of rounds for communication of information. Each round starts with set-up phase and followed by the steady phase.

In first phase i.e. setup phase cluster creation and CH selection was take place. CHs selection choice is prepared by the each node select a random number between 0 and 1. Threshold $T(n) = \frac{P}{1 - P(r \mod \frac{1}{P})}$ calculated to check a node has chance to become CHs for current round. In this P is desire percentage of CHs, r is the number of current round. If node contains value less than $T(n)$ it becomes CHs for current round and cannot be CHs for the next $\frac{1}{P}$ rounds. Therefore probability of remaining nodes must be increased. After this in steady phase CHs node receives all data from local nodes compress it and send it to the sink. LEACH is an effective technique to reduce energy dissipation, enhanced network lifetime. Distributed Energy Efficient Clustering (DEEC) [11] is used for heterogeneous WSNs. In DEEC, the CHs chosen by a possibility based on the ratio between the remaining energy of every node and the average energy of the WSNs. The round number of the rotating period for every sensor node is dissimilar to its initial and remaining energy. The sensor nodes with maximum initial and remaining energy will have more chance to become the CHs than normal nodes. In LEACH every node has chance to become a CHs after $\frac{1}{p}$ rounds. All the nodes cannot same remaining energy when sensor network evolves so, the energy will be not well distributed and the low-energy nodes will finish earlier than the high-energy nodes. For CH choice, DEEC uses initial and remaining energy level of nodes. DEEC provides good performance in the networks containing normal and advanced nodes. Developed Distributed Energy-Efficient Clustering (DDEEC) [15] allows to balance the cluster head selection overall WSNs nodes following their remaining energy. DDEEC uses same method for estimation of average energy and CH selection algorithm based on remaining energy as
applied in DEEC. In DDEEC nodes that have maximum energy values and more remaining energy has more possibility to become CH than nodes having lower energy, so, in these way advanced nodes will become CHs more often as compared to normal nodes. After some period advanced nodes having same remaining energy like normal nodes. Although, DEEC continues to punish the advanced nodes so this is not best way for energy distribution, because after this advanced nodes are continuously be a CH and they expire faster than normal nodes. To avoid this problem DDEEC presents a threshold residual energy. When advanced and normal nodes energy level less than threshold residual energy then both types of nodes use same probability to become cluster head. Therefore, CH selection is balanced and more efficient in DDEEC. Enhanced Distributed Energy Efficient Clustering (EDEEC) [16] scheme uses the idea of DEEC with addition of super nodes and expands it into three level heterogeneity WSNs. It includes three types of nodes i.e. normal, advanced and super nodes with their probabilities based on initial energy. Enhanced Developed Distributed Energy Efficient Clustering (EDDEEC) [2] scheme is used for three-level heterogeneous WSNs. It uses same method for CH selection based on initial, remaining energy level of the nodes and average energy of network as in DEEC. At beginning of the round, each node make a decision whether to become a CH or not for current round based on Threshold But in 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 [16]. 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. Same issue with DEEC, it also continues to penalize just advance nodes and DDEEC [15] is limited only for two-level heterogeneous networks. To eliminate this unbalanced

4. 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area(x,y)</td>
<td>100,100</td>
</tr>
<tr>
<td>Base station(x,y)</td>
<td>50,50</td>
</tr>
<tr>
<td>Nodes(n)</td>
<td>100</td>
</tr>
<tr>
<td>Probability(p)</td>
<td>0.1</td>
</tr>
<tr>
<td>Initial Energy(En)</td>
<td>0.1</td>
</tr>
<tr>
<td>transmitter_energy</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>receiver_energy</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Free space(amplifier)</td>
<td>10nJ/bit/m2</td>
</tr>
<tr>
<td>Multipath(amplifier)</td>
<td>0.0013pJ/bit/m4</td>
</tr>
<tr>
<td>a (energy factor between normal and super nodes)</td>
<td>3</td>
</tr>
<tr>
<td>b (energy factor between normal and advance nodes)</td>
<td>2</td>
</tr>
<tr>
<td>Maximum lifetime</td>
<td>2500</td>
</tr>
<tr>
<td>Message size</td>
<td>4000 bits</td>
</tr>
<tr>
<td>m (fraction of advanced nodes)</td>
<td>0.3</td>
</tr>
<tr>
<td>x(fraction of super nodes)</td>
<td>0.3</td>
</tr>
<tr>
<td>Effective Data aggregation</td>
<td>5nJ/bit/signal</td>
</tr>
</tbody>
</table>

5. Experimental Results

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 make a decision whether to become a CH or not for current round based on Threshold But in 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 [16]. 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 [15] 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 $T_{\text{absolute}}$, that is the value in which advance and super sensor nodes have similar energy level as in case of normal nodes. Using $T_{\text{absolute}}$ all kinds of nodes has identical probability for CH selection.

$$P_{\text{opt}} = \frac{1}{(1+m(a+m+b))E(r)}$$

for normal nodes if $E_i(r) > T_{\text{absolute}}$, \hspace{1cm} (1)

$$P_{\text{opt}} = \frac{(1+a)E_i(r)}{(1+m(a+m+b))E(r)}$$

for advance node if $E_i(r) > T_{\text{absolute}}$, \hspace{1cm} (2)

$$P_{\text{opt}} = \frac{(1+b)E_i(r)}{(1+m(a+m+b))E(r)}$$

for super nodes if $E_i(r) > T_{\text{absolute}}$, \hspace{1cm} (3)

$$c \frac{P_{\text{opt}} (1+b)E_i(r)}{(1+m(a+m+b))E(r)}$$

Otherwise \hspace{1cm} (4)

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

The results of EDDEEC are shown below:

Fig.3 is showing the active environment of EDDEEC. Green diamond is representing the base station. Magenta circle nodes are representing the normal sensor nodes. Cyan circle nodes are representing the advance nodes and green circle nodes representing the super sensor nodes. Red stars are representing the cluster heads. Red lines are representing how data communicate to the base station.

Fig.4 is showing the environment of EDDEEC in which some of the nodes are dead. Dead nodes are representing by red dot. Magenta circle nodes are representing the normal sensor nodes, cyan circle representing the advance nodes and green circle nodes representing the super sensor nodes. Green diamond is representing the base station.

Fig.5 is showing the end of the sensor environment of EDDEEC where all the nodes are dead.

Fig.6 is showing the remaining energy. X-axis is representing the energy in joules. Y-axis is representing the number of rounds.
6. Proposed Algorithm

The proposed algorithm will function in four stages:

**Step 1:** In the first step, initialize the WSNs with required parameters like nodes position, sink position, initial energy of each kind of nodes etc.

**Step 2:** In the second step, for every node i repeat the following steps until all nodes become dead.

**Step 3:** In the third step, select cluster head using following equations i.e. normal (eq.5), advance (eq.6), super nodes (eq.7) and for all types of nodes having same remaining energy (eq.8).

\[
P_{opt} \frac{E_i(r)}{(1+m(a+m_o)b)E(r)} * \text{Fuzzy cost for normal nodes if } E_i(r) > T_{absolute}
\]
\[
P_{opt} \frac{(1+a)E_i(r)}{(1+m(a+m_o)b)E(r)} * \text{Fuzzy cost for advance node if } E_i(r) > T_{absolute}
\]
\[
P_{opt} \frac{(1+b)(r)}{(1+m(a+m_o)b)E(r)} * \text{Fuzzy cost for super nodes if } E_i(r) > T_{absolute}
\]
\[
E_{opt} \frac{(1+b)E_i(r)}{(1+m(a+m_o)b)E(r)} * \text{Fuzzy cost for nor, adv, sup nodes if } E_i(r) \leq T_{absolute}
\]

Where Fuzzy cost will vary according to the nodes behavior and its neighbors.

**Step 4:** In the fourth step, evaluate the energy dissipation and update the remaining energies it. Where distance will be evaluated using eq. 9 [2] and updating of energy will be based upon the eq. 10 [13] and eq. 11 [13].

\[
d_{toCH} = \frac{M}{\sqrt{2}\pi k}, \quad d_{toBS} = 0.765 \frac{M}{2}
\]
\[
E_{TX}(l,d) = 1 E_{elec} + l E_{mp} d^4, \quad d < d_0
\]
\[
E_{TX}(l,d) = 1 E_{elec} + l E_{mp} d^4, \quad d \geq d_0
\]

On applying fuzzy cost functions, following results will be achieved.
Fig. 10 is showing the active environment of fuzzy based EDDEEC. Green diamond is representing the base station. Magenta circle nodes are representing the normal sensor nodes. Cyan circle nodes are representing the advance sensor nodes and green circle nodes are representing the super sensor nodes. Red stars are representing the cluster heads. Red lines are showing the Communication between member nodes to cluster head.

Fig. 11 is showing the environment of fuzzy based EDDEEC in which some of the nodes are dead. Dead nodes are representing by red dot. Magenta circle nodes are representing the normal sensor nodes, cyan circle representing the advance nodes and green circle nodes representing the super sensor nodes. Red lines are showing the Communication between member nodes to cluster head.

Fig. 12 is showing the remaining energy. X-axis is representing the energy in joules. Y-axis is representing the number of rounds.

Fig. 13 is showing total number of packet sent to base station. X-axis is representing number of packets. Y-axis is representing the number of rounds.

Fig. 14 is showing total number of packet sent to cluster head. X-axis is representing number of packets. Y-axis is representing the number of rounds.

Fig. 15 is showing total number of dead nodes. X-axis is representing dead nodes. Y-axis is representing the number of rounds. It is showing that the first node dead at 356 round and last node dead at 2107 round.
Table 2 has shown the comparison between DEEC, EDEEC, EDDEEC AND FEDDEEC with respect to first node dead and last node dead time.

Table 2: Comparative analysis

<table>
<thead>
<tr>
<th>Protocols</th>
<th>First node dead</th>
<th>Last node dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEEC</td>
<td>154</td>
<td>727</td>
</tr>
<tr>
<td>EDEEC</td>
<td>187</td>
<td>1343</td>
</tr>
<tr>
<td>EDDEEC</td>
<td>235</td>
<td>1402</td>
</tr>
<tr>
<td>FEDDEEC</td>
<td>332</td>
<td>2087</td>
</tr>
</tbody>
</table>

7. Conclusion

It has been found from the survey that the most of the existing researchers has worked hard to prolong the network lifetime. This has come up with significant improvement over the existing protocols like LEACH. But it is also found that the most of the researchers has neglected many issues. This research work has proposed an improvement for the heterogeneous WSNs using fuzzy based cluster head selection. The EDDEEC has used different probability function for selecting the best cluster head by using the residual energy and average energy of the network. But EDDEEC has neglected the use of number of neighbors of sensor nodes during cluster head selection. So this work has proposed new Tabsolute and fuzzy based heterogeneous protocol. The fuzzy cost will be evaluated on the basis of the residual energy and the node centrality. The fuzzy cost will be dynamic in nature as it is evaluated in each round. 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 the significant improvement of the proposed protocol over others.

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.

REFERENCES


