CHAPTER 4

ENHANCING ENERGY EFFICIENCY OF WIRELESS SENSOR NETWORK THROUGH THE DESIGN OF ENERGY EFFICIENT ROUTING PROTOCOL

4.1 Introduction

The sensor nodes are operated with limited energy sources. More energy dissipation happened in the communication. The energy spend by node subject to the distance of communicated node (Nabil Sabor et al 2017). The different method choose for data transfer over the networks. Flat based and hierarchical based are best example. In flat based data communicated In a hierarchical methods applied in WSN for organizing the nodes such clusters topology. The cluster formation follows requirements and metrics.

4.2 Cluster Based Routing

Clustered tools are predominantly more fit for wireless sensor networks with constant data flowing. The cluster established routing is energy resourceful way in which nodes those taking great energies are subjectively selected for meting out and sending data whereas nodes those taking little energies are used for sending information to cluster heads. The stuff of cluster built routing pays to the scalability, lifetime expansion, and energy minimization. The cluster built routing protocols performance a vital role in attaining application precise goals. Figure 4.1 shows the clustering of WSN.
The cluster based routing protocols are classified into three broad categories: block cluster based, grid cluster based and chain cluster based routing protocols (Chanchal Sharma and Vishwajeet Pattanik 2016). The widespread block cluster built routing protocols are LEACH, HEED, UCS, EECS, TEEN, etc. The popular grid cluster built routing protocols are PANEL, GAF, TTDD, SLGC, etc. The popular chain cluster built routing protocols are PEGASIS, CCS, TSC, etc. There are quiet some issues to be addressed for the effective use of cluster built routing protocols. They are

- Calculation and Choice of Cluster Heads

The process of selecting a node as a cluster head is very important. This selection must properly be done considering the remaining energy of every node (Eid Rehman et al 2017). There has to be a threshold energy level below which the network must readily hop from node to node.

- Scalability
Few nodes in the network remain attended when the deployment is over a wide area. The governing area must be considerable increased.

- **Topology of network**

  Network topology can change depending upon the terrestrial area where a particular network is functioning. More efficient clustering mechanisms need to be followed to improve network efficiency.

- **Fault tolerance**

  The sensor nodes should be self sufficient to handle minor faults.

- **Redundancy Management**

  Network needs to be designed with minimum number of possible nodes without compromising the accuracy and security.

Moreover attaining energy effectiveness, clustering decreases channel contention and packet a smash, ensuing in improved network throughput in great load. In addition to assistant network scalability, clustering has several benefits. It can focus the route set up inside the cluster and consequently decrease the size of the routing table kept in the single node. Clustering be able to protect communication bandwidth subsequently it bounds the choice of inter-cluster communications to CHs and evades redundant (Kyuhong Lee and Heesang Lee 2011).
4.3 Proposed Scheme

The two likely energy wounded that a sensor node workouts in a sensor network are energy gone during sensing and communication cost. The energy cost in communication is much higher than the drive less in sensing. Therefore, planned to minimize the considerable communication cost by clustering. The main stages of the offered method are named Distributed Clustering based Energy Efficient Routing (DCEER) protocol includes

i) Cluster Head Selection

ii) Cluster Formation

iii) Data Transmission

In this offered protocol, new Cluster Head (CH) is nominated by the present CH in its place based on the maximum residual energy and minimum space among the CH and a node in a cluster. Also, re-clustering is taken place only as soon as the residual energy of the present CHs lesser than a threshold value.

4.3.1 Cluster Head Selection

The cluster head appointment has founded on the fitness function value. It provides a guide to the nodes on the network. The scheme help to reduce the energy loss of the system. The node which has high function values become cluster head. Fitness Function of node ‘i’ is defined as follows.

\[ fit_i = \frac{1}{E_i} + \frac{1}{NC_i} \]  \hspace{1cm} (4.1)
Now $E_i$ denote energy of Node and $NC_i$ denote node centrality. The Node Energy defined as

$$E = n * E_R + (n + 1) * E_{agg} + E_T$$  \hspace{1cm} (4.2)$$

Let, $n$ denote total node, $E_R$ denote reception energy, $E_{agg}$ denote combine energy, and $E_T$ denote transmit energy of CH to sink. Node to CH transmit energy has expressed as follow

$$E_R = kE_{elec}$$  \hspace{1cm} (4.3)$$

At this juncture, $k$ bits message transfer to the sink from CH based on the threshold value. Suppose the space value of node minimum to the threshold then energy calculation has defined as

$$E_T (d < d_0) = kE_{elec} + kE_{mp}d^2$$  \hspace{1cm} (4.4)$$

Otherwise space value is higher to threshold value, then energy calculation has defined as

$$E_T (d > d_0) = kE_{elec} + kE_{mp}d^4$$  \hspace{1cm} (4.5)$$

Now aggregation energy has calculated by total spent for data gathering. It value is constant that is defined,

$$E_{agg} = 5nJ$$  \hspace{1cm} (4.6)$$

The node centrality (NC) has calculated on the networks by the equation

$$NC_i = (n - 1)\sqrt{x_m^2 + y_m^2}$$  \hspace{1cm} (4.7)$$
The probability value has created for lower and upper level using fitness function. The lower level value is calculate by sum of fitness value of each nodes.

\[ Lower\ Level\ Value(L) = \frac{\sum_{i=1}^{n} fit_i}{n} \tag{4.8} \]

The upper-level value is calculate by sum of square of fitness value of each nodes.

\[ Upper\ Level\ Value(U) = \frac{\sum_{i=1}^{n} fit_i^2}{n} \tag{4.9} \]

The CH has identified by the probability \((p)\) is between two levels.

### 4.3.2 Cluster Formation

Once selecting the cluster head by using distance function. The distance between each node and each cluster heads has calculated. The average value between two calculated as.

\[ Average = \frac{\sum_{i=1}^{n} d(mem, CH)}{n_{CH}} \tag{4.10} \]

Now \(d\) (mem, CH) denotes distance between node to CH, \(n_{CH}\) denotes No. of CH. So nodes have lowest variance in length among its member as a CH.

\[ Distance\ Function = \sum_{i=1}^{q} d(mem, CH) - Average \tag{4.11} \]

Based distance cost, the nodes with the lowest space forms a cluster. So that takes an equal quantity of nodes in apiece cluster, a steady factor has used which has
only restricted amount of affiliate nodes — the node that first tactics a cluster head will link with the cluster head to form clusters. After the bound finished the number of affiliate nodes takes grasped, the outstanding nodes have to discover the subsequent adjacent affiliate node. So, built on this way, the cluster creation has completed.

4.3.3 Data Transmission

This stage is answerable for data communication between cluster participant, CHs and the base station.

![Diagram of Next-hop forwarding node selection process]

Once the cluster establishment, every cluster head computes the weight value created on the space among the equivalent cluster head and the base station. It has expected that apiece node identifies the place of the base station. The weight value of the respective cluster head has designed on the following formula
\[ W(i) = \frac{D_{ib}}{D_{\text{max}}} E_{\text{residual}}(i) \]  

(4.12)

where \( D_{\text{max}} \) is the maximum transmission choice. \( D_{ib} \) is the space among the cluster head i and the base station b. \( E_{\text{residual}}(i) \) is the residual energy of the cluster head i. Before a piece cluster head announce a message (WGT_ANN) which contains weight factor and its ID to every other adjacent cluster heads. The succeeding hop promoting node choice is described in Figure 4.2.

When the other cluster heads receive the transmission message, it matches its weight value through the received one. Suppose the received weight value is more than its weight value, at that time it accepts that cluster head like this one succeeding hop sending node. Otherwise, the received weight value is fewer than its weight value, at that moment it converts the succeeding hop sending node to the accepted individual. The method will have sustained until the packet move to the base station. Later a predefined time, the present round originate to a finish and the subsequent round starts, convoyed by new CHs selection and cluster formation.

4.4 Simulation And Results

4.4.1 Simulation study

This work is simulated over the Network Simulator 2.32. Sensor nodes are randomly deployed into 200x200m2 area of interest. Every sensor nodes are assigned to the identical hardware and transmission power. The performance is evaluated by comparing with related schemes DEER, DEGRA and LGCA. The model results are studied by changing the network size from 50 to 300 and by varying the number of
rounds from 200 to 1000. The results are simulated over different simulation topologies. The parameters applied in simulation are tabulated in Table 4.1.

Table 4.1.Parameter settings for simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of deployment</td>
<td>200m × 200m</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>50-300</td>
</tr>
<tr>
<td>Packet Length</td>
<td>5000 bits</td>
</tr>
<tr>
<td>Initial energy of the sensor nodes</td>
<td>2 J</td>
</tr>
<tr>
<td>Transmission range</td>
<td>5m</td>
</tr>
<tr>
<td>Mobility Speed</td>
<td>10m/s.</td>
</tr>
<tr>
<td>Simulation time</td>
<td>50-400 sec</td>
</tr>
<tr>
<td>Energy consumption on circuit</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Energy consumed in Sleep state</td>
<td>3 μJ</td>
</tr>
<tr>
<td>Base station location</td>
<td>(100,150)</td>
</tr>
</tbody>
</table>

4.4.2 Algorithms used for Comparison

E-LEACH (Energy-LEACH) is a revised cluster routing algorithm to improve the hierarchical routing protocol LEACH. Now the E-LEACH procedure, the new way of the selecting of the cluster heads by random, and the round time for the choice is stable. Subsequently, remaining energy of node as the key metric elects whether the nodes chance into CH or not afterward the first round.

Energy Efficient Clustering-based Protocol (EECP) is clustering based protocol for single-hop, heterogeneous networks. It practices channel state information (CSI) in the key factor to identify the Cluster Heads (CHs). At this juncture nodes with diverse energy, points have measured affecting heterogeneity in the network — besides, a single-hop communication tactic has implemented for intra-cluster and inter-cluster communication. Also, an improved routing structure has planned where the focus is to improve cluster head choice process. CHs nominated in every cluster based on residual node energy and the most significant channel.

Energy Aware Cluster Based Routing Scheme (EACBRS) intentions to preserving energy with the support of hierarchical routing through shrewd the most exceptional amount of cluster heads for the network, picking the energy-efficient route to the sink by influence congestion control. The base station shows the part of choosing the necessary quantity of cluster heads for respective level and reflect in the right spreading of the head nodes done the network area. Cluster creation has not frequent, and it is constant simply once new nodes arrive the network area.
4.4.3 Results and Discussion

The performance of DCEER has measured through network energy consumption, network lifetime in terms of number of alive nodes, packet delivery ratio in static and mobility condition, throughput and end-to-end delay.

Energy consumption: Energy consumption for single round of communication from source to destination is determined by the average energy which is consumed to deliver a packet successfully from a source node to the base station. If every hop along a path has the same energy level and the same energy consumption for sending and receiving the message, then hop-per delivery is considered to determine the energy consumption (Prabhudutta Mohanty and Manas Ranjan Kabat 2014).

Network lifetime: The primary objective of energy efficient organizations and power conservation policies is to encompass the network life period given that potential. It is an energy-based metric. It has distinct by way of the time on which the first node death occurs. That can also have described as the time in which some node’s energy reserved is returned to zero (Avinash Morea and Vijay Raisinghani 2017).

Packet delivery ratio: To determined as the ratio of the number of packets successfully delivered with packets generated from the source along the path. It shows the capability of the planned mechanism which may provide the data to the destination. How efficiently the network delivers data to the required authorities (Mashrur-E-Elahi et al 2012).
Throughput: It calculated by the total amount of bits fruitfully sent to the target in a decided period. The ratio of entire data received by a receiver from a sender for a period of time. The unit has measured in bit/sec or byte/sec. (Geetika Ganda and Prachi Shaily Mittal 2011).

End-to-End Delay: It is a time difference between packet generated and reached to the destination. So many reasons for delay may happen on the networks due to route gaining, queueing at intermediate nodes for forward, retransmission delays, etc. End-to-end delay mostly affected by network congestion (Ibrahim Alabdulmohsin et al 2014).

Figure 4.3 shows the simulation results of energy consumption of the E-LEACH, EECP and EACBRS with the DCEER protocol for a network of size 200 nodes. The DCEER has lower network energy consumption matched to the other protocols. The total energy depletion of the DCEER is 125 joules during 600 rounds and 195 joules for a maximum of 1000 rounds because in DCEER, a node chooses energy value which depends on distance between the node to the cluster head and initial and residual energy of the node. But other protocols spent energy between 165 and 220 joules during 600 rounds and between 240 and 345 joules for a maximum of 1000 rounds. In DCEER, there was 50% of energy remaining in the network even after 1000 rounds due to the minimizing of the routing overhead.
Figure 4.3 Comparison of network energy consumption

Figure 4.4 Comparison of alive nodes

Figure 4.4 shows the number of alive nodes comparison of all routing protocols with that of DCEER for a network of size 200 nodes. In DCEER protocol, has 190 nodes alive during 200 rounds but the number of nodes alive is from 140 to 175 in other protocols. Also, DCEER achieves 150 nodes alive during 600 rounds. But in the case of the other protocols, the sum of nodes alive is from 90 to 125. The network lifetime is directly related to the energy consumption of the nodes, since the DCEER protocol uses energy aware utility function for picking a cluster head.
between the sensors to evade exhausting the battery. Thus, the energy burden of presence cluster head has uniformly distributed between the nodes. Hence, the number of alive nodes of the DCEER protocol is higher than the other protocols.

Figure 4.5 shows the packet delivery ratio of all the protocols after 200th round for static network condition compared with the DCEER protocol. It is observed that the delivery ratio of the proposed protocol DCEER is 70% for a network size of about 250 nodes. For all the other protocols, the packet delivery ratio is only between 40% and 60%. For a network size of about 300 nodes, the packet delivery ratio of the DCEER is also nearly 60% but for the other protocols it is only from 30% to 50%. Because DCEER uses the weight factor calculation for the next hop selection to establish the routing path. It depends upon the space between the cluster head to the base station and the residual energy of the CHs. Thus DCEER achieves good packet delivery ratio in static condition compared with the other protocols.
Figure 4.6 Packet delivery ratio in mobility condition

Figure 4.6 shows the packet delivery ratio analyzed in a mobile network analyzed with the DCEER for a network of size 100 nodes. It is noticed that even for 20% of nodes in mobility condition, the proposed protocol shows 80% of packet delivery ratio and all other protocols show only 40% to 65% packet delivery ratio because DCEER maintains a candidate list for selecting cluster heads to tolerate the connection loss when agility. In 40% of nodes in mobility condition, the proposed protocol shows 62% of delivery ratio. But for all the other protocols, it is only between 24% and 50%. Hence, the delivery ratio of DCEER is more compared with the other protocols in mobility condition.
Figure 4.7 Throughput comparison

Figure 4.7 shows the throughput of DCEER is analyzed with the other protocols. The throughput of DCEER is 1.4kbps for 400 rounds, but other protocols have the value from 0.55 to 1kbps. Because of DCEER increases the forwarding rate of packets by selecting the neighbor nodes having the maximum remaining energy levels. The throughput of DCEER is 3.2kbps for a maximum of 1000 rounds, but the other protocols EECP and EACBRS have throughput 2kbps and 2.5kbps respectively. The improvement in throughput of DCEER is due to the delivery of more packets successfully from source to sink by picking the path established on residual energy levels of nodes.
Figure 4.8 End-to-end delay comparison

Figure 4.8 shows the end-to-end delay of DCEER protocol has lesser delay to analyzed with other protocols in various sizes of network. The end-to-end delay of the DCEER is 1.8 seconds for a network of size 300 nodes. For the other protocols it ranges from 2 to 3.2 seconds. The delay of the DCEER protocol is 0.8 seconds for a network of size 200 nodes, whereas for the other protocols it is between 1 and 1.5 seconds. Because of considering the space between the cluster head to the base station by weight factor calculation.

Table 4.2 shows the comparison of DCEER with the existing protocols for different parameters. The parameters may be network energy consumption, number of alive nodes, packet delivery ratio in static and mobility conditions, throughput and end-to-end delay.
Table 4.2 Comparative analysis of DCEER with the existing schemes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>E-LEACH</th>
<th>EECP</th>
<th>EACBRS</th>
<th>DCEER (Proposed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption for a network of size 200 nodes after 600 rounds (joules).</td>
<td>220</td>
<td>190</td>
<td>165</td>
<td>125</td>
</tr>
<tr>
<td>Number of nodes alive for a network of size 200 nodes after 800 rounds.</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>130</td>
</tr>
<tr>
<td>Packet Delivery ratio for a network size of about 250 nodes in static condition after 200 rounds.</td>
<td>0.45</td>
<td>0.55</td>
<td>0.7</td>
<td>0.77</td>
</tr>
<tr>
<td>Packet Delivery ratio for 30% mobility of nodes of a network size 100 nodes.</td>
<td>0.32</td>
<td>0.48</td>
<td>0.58</td>
<td>0.72</td>
</tr>
<tr>
<td>Throughput for a network of size 300 nodes after 600 rounds (kbps).</td>
<td>0.8</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>End-to-End delay for a network of size 150 nodes (seconds).</td>
<td>1.2</td>
<td>0.9</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>

4.5 Summary Of Contributions

This chapter presents a routing protocol named DCEER for successful energy efficiency, which prolongs the network lifetime. In addition that utility function is framed for picking the proper cluster head. Formerly the weight factors has applied to make the energy capable routing path to afford energy effective routing. A node have greater residual energy be able to be nominated as the cluster head. The DCEER algorithm minimize the energy depletion of the node also extends the life duration of the network. DCEER has compared with the widespread algorithms such as E-LEACH, EECP and EACBRS. DCEER express an improved enactment in terms of fewer energy consumption, concentrated quantity of nodes alive, greater packet delivery ratio, higher throughput and least end-to-end delay.