CHAPTER 9: CONCLUSION AND FUTURE WORK

9.1 Summary

Wireless Sensor Networks (WSN) is a promising technology for monitoring the environment where human involvement is not possible or not needed. In organizing these miniature sensor nodes as a single system various models are there. Out of all these models clustering is best suited for WSN because of its features such as adaptability, robustness, scalability and energy efficiency. Again these clustering algorithms should be designed in such a way to achieve energy balancing and energy conservation which are the strict design restrictions of WSN. This dissertation contributes new clustering algorithms based on Fuzzy logic, genetic algorithms and graph theory concepts. The proposed algorithms are designed considering the design restriction of WSN and increases the lifetime of the network.

Chapter 1 in this dissertation introduce to WSN technology, its applications, different data dissemination techniques and the contributions of this dissertation. In Chapter 2, different features and objectives of the clustering are discussed in detail. A new classification scheme is introduced and the presented algorithms are classified based on it. The network model used for simulating the proposed and existing algorithms is discussed in Chapter 3. Chapter 4 to 8 explains the new clustering algorithms and their simulations using the network model described in Chapter 3 along with other similar algorithms. The results are also discussed in detail in respective chapters.

9.1.1 DUCF:

Distributed Unequal Clustering using Fuzzy approach (DUCF) is the fuzzy based unequal distributed clustering algorithm. Hot spot problems associated with the multi-hop routing
between Cluster Head (CH) and Base Station (BS) is handled in DUCF by forming unequal clusters. The size of the cluster is made to be small if it CH is near to BS since the CH may act as a relay node for distant CH nodes. DUCF achieves increased lifetime than others by strictly restricting the size of a cluster according to its CH capacity.

9.1.2 FLECH:
In non-uniform deployment of sensor nodes, weight based CH election will lead to undesirable results. Fuzzy Logic based Energy efficient Clustering Hierarchy (FLECH) is another fuzzy based distributed clustering algorithm proposed in this thesis considering the non uniform node deployment in the ROI. At first, FLECH elects probationary CHs through probabilistic approach. Later, final CHs are elected through competition based on fuzzy based weights among these probabilistic CHs. FLECH combines both probabilistic and weight based CH so that CH responsibility is rotated among the nodes in the network.

9.1.3 GAECH:
Genetic algorithms play a major role in clustering aspect of WSN. In literature, various genetic algorithms based clustering have been proposed. But the existing works concentrated on reducing the energy consumption than balancing the energy consumption among the nodes in the network. Genetic Algorithm based Energy efficient Clustering Hierarchy (GAECH), the centralized clustering algorithm solves this problem through novel fitness function which aims to balance the energy consumption and also energy reduction in the network. Also, the major problem with centralized algorithm is scalability issue. But GAECH was designed in such a way that scalability also does not affect the performance of the network.
9.1.4 EEGTP:

Graph theory is a widely used technique for optimization problems in engineering field. Generally CH nodes are found to be spending energy 10 times more than a CM node. Energy Efficient Graph Theory based Protocol (EEGTP) is designed in such a way that the CHs energy consumption activities are shared with its member nodes. CHs are only involved in transmitting the aggregated data to BS. Then, the aggregated data from distant CH to the BS is communicated in multi-hops. Data reception and aggregation costs were shared among the member nodes. The main goal of EEGTP is to increase the network lifetime through energy balancing between CH and CM nodes.

9.1.5 EECDC:

Energy Efficient Coverage aware Data Collection (EECDC) is another graph theory based clustering algorithm proposed in this thesis. EECDC avoids the generation of redundant data by using logical clustering concepts. This logical clusters are created using MIS concepts in graph theory. A logical cluster is the set of nodes whose coverage or sensing radius $R_S$ should be non-overlapping. By activating these clusters one after another, the entire Region of Interest (ROI) would be sensed in discrete time interval.

The proposed algorithms such as DUCF, FLECH, GAECH, EEGTP and EECDC in this dissertation are compared based on time complexity, node mobility, cluster overlap and topology followed.
Table 9.1: Comparison of proposed algorithms

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>Time Complexity</th>
<th>Node Mobility</th>
<th>Cluster overlap</th>
<th>Topology</th>
</tr>
</thead>
<tbody>
<tr>
<td>DUCF</td>
<td>$O(n)$</td>
<td>Static</td>
<td>Non-overlapping</td>
<td>Random</td>
</tr>
<tr>
<td>FLECH</td>
<td>$O(n)$</td>
<td>Static</td>
<td>Non-overlapping</td>
<td>Non-uniform</td>
</tr>
<tr>
<td>GAECH</td>
<td>$O(g^<em>p^</em>((O(f)^*q(O(c)+O(m)))))$</td>
<td>Static</td>
<td>Non-overlapping</td>
<td>Random</td>
</tr>
<tr>
<td>EEGTP</td>
<td>$O(n)$</td>
<td>Static</td>
<td>Non-overlapping</td>
<td>Random</td>
</tr>
<tr>
<td>EECDC</td>
<td>$O(n^2)$</td>
<td>Static</td>
<td>Non-overlapping</td>
<td>Random</td>
</tr>
</tbody>
</table>

9.2 Future Work:

Clustering algorithms based on fuzzy, genetic algorithm and graph theory are proposed in this dissertation with simulation results. In future, further research in WSN will continue and the theoretical methods will be applied in the real sensor network platform. Also, the following aspects are to be studied in future for further improving clustering architecture in WSN.

- **Clustering algorithms for heterogeneous networks**: In this dissertation all the proposed algorithms falls under homogeneous network type. The strategies followed for homogeneous networks would not be suitable for heterogeneous networks. So based on the techniques which are suitable for heterogeneous network, clustering should be applied.
• **Using mobile node for data collections**: The mobility issue is not considered in this dissertation. In future the BS may be a mobile node moving in the ROI at frequent interval of time to collect data from CH or from member nodes directly. The clustering strategy followed for static BS should be redesigned in such a way to suit mobile BS.

• **Clustering algorithms for event based monitoring**: All the proposed algorithms in this dissertation are for periodic monitoring applications. In certain application instead of periodic monitoring, event based monitoring is needed. Whenever an event is detected, dynamically a cluster should be formed around the event area by the co-located sensor nodes. The formed clusters would be short lived till the event detection ends. So new metrics should be used for forming these types of clusters in the future.