A Fuzzy Based Clustering Technique for Wireless Sensor Networks

Ashish Kumar¹, Er. Sushil Kamboj²

¹M.Tech. Scholar, CSE Department, SUSCET-Tangori
²Principal, SUSCET-Tangori

Abstract— All nodes in a network can be organized in hierarchical structures called clusters. Each cluster consists of a cluster head and several member nodes. The member nodes collect data and send it to their cluster heads. The cluster head aggregates and transmits the data to the Base Station. The energy consumption of cluster heads is higher than that for member nodes. Clustering algorithms are required which can efficiently utilize the energy of nodes so that life of network can be increased. In this work we will implement fuzzy logic using which the best cluster head can be elected from the network. The election of Cluster Head is very important aspect in this field because the life time of network is directly depends on life time of cluster head. Each non-Cluster Heads selects the best Cluster Head by considering residual energy of Cluster Head and a distance from non-Cluster Heads to Base Station (Sink). These two member functions i.e. residual energy of Cluster Head and a distance from non-Cluster Head to Base Station (Sink) are used in Fuzzy System to give the best probability results for a cluster head to be elected.

Keywords— WSNs, SNs, BS, CH, Non-CH

I. INTRODUCTION

A Wireless sensor network is composed of tens to thousands of sensor nodes which are densely deployed in a sensor field and have the capability to collect data and route data back to base station. Wireless Sensor Network is used in many application now a days [14], such as detecting and tracking troops, tanks on a battlefield, measuring traffic flow on roads, measuring humidity and other factors in fields, tracking personnel in buildings. Sensor nodes consist of sensing unit, processing unit, and power unit.

1.1. Challenges for WSN

The main design goal of wireless sensor networks is to transmit data by increasing the lifetime of the network and by employing energy efficient routing protocols. Depending on the applications used, different architectures and designs have been applied in sensor networks. Again, the performance of a routing protocol depends on the architecture and design of the network, so the architecture and design of the network is very important features in WSNs. The design of the wireless sensor network is affected by many challenging factors which must be overcome before an efficient network can be achieved in WSNs. In the following section we try to describe the architectural issues and challenges for WSNs.

- Node Distribution [1]
- Dynamicity
- Energy efficiency
- Data Transmission
- Scalability

1.2. Characteristics of WSN

Due to a lack of infrastructure, SNs need to cooperate with each other so as to maintain life and secure information. Each SN not only acts as a host, but also as a router for data forwarding. Each SN has limited power, memory storage, data processing capacity and radio transmission range [6]. Generally, a WSN has the following characteristics:

- Ad hoc Deployment
1.3. Clustering in WSNs
The major advantage of wireless sensor network (WSN) is the ability to deploy it in an ad-hoc manner [7], as organizing these nodes into groups pre-deployment is not feasible. For this reason, a lot of research has been conducted into ways of creating these organizational structures (or clusters) [8]. A clustering scheme divides the sensor nodes in a wireless sensor network (WSN) into different virtual groups, according to some set of rules. In a cluster structure, sensor nodes may be assigned a different status or function, such as cluster head or cluster member [9].

1.4. Clustering Algorithms
Many algorithms have been proposed for routing in WSN. Clustering algorithms have gained popularity in this field. Clustering algorithms can be classified as:

- Distributed algorithm,
- Centralized algorithm,
- Hybrid algorithm

In distributed clustering techniques, any node can choose itself as a cluster head (CH) or join an already formed cluster on its own initiative, independent of other nodes. Distributed clustering techniques are further classified into four sub types based on the cluster formation criteria and parameters used for cluster head (CH) election as identity based, neighborhood information based, probabilistic and iterative. In centralized methods [10], the base station requires global information of the network to control the network. Cluster heads (CHs) are elected by the base station. Hybrid schemes are composed of centralized and distributed approaches. In a hybrid environment, distributed approaches are used for coordination between CHs, and centralized schemes are followed for cluster heads (CHs) to build individual clusters. In design of routing protocols for WSN, clustering algorithms have following advantages:

- Clustering reduces number of nodes taking part in long distance transmission.
- Clustering algorithms are scalable for large number of nodes.
- They reduce communication overhead.

II. LITERATURE SURVEY

Heinzelman et al. [2], LEACH (low-energy adaptive clustering hierarchy) proposed by Heinzelman et al. [2], was one of the pioneering clustering routing approaches for WSNs. It divides the protocol operation into rounds, and each round was subdivided into two phases: setup and steady-state phase. In the setup phase, the nodes create clusters and elect CH. In the case of the steady state phase, non-CHs transmit the sensed data to their CH. cluster heads (CHs) receive the data, aggregate it into a single packet and forward it to the BS. After a certain period of time the network returns to the setup phase.

Younis and Fahmy et al [3], Hybrid Energy-Efficient Distributed clustering (HEED) [3], introduced by Younis and Fahmy, was a multi-hop wireless sensor network (WSN) clustering algorithm which brings an energy-efficient clustering routing with unambiguous thought of energy. Different from LEACH in the manner of cluster head (CH) election, HEED does not select nodes as cluster heads (CHs) arbitrarily.

Loscri et al. [4], Two-Level Hierarchy LEACH (TL-LEACH), presented by Loscri et al. [4], was an addition to the algorithm of LEACH. TL-LEACH uses the following two techniques to achieve...
energy and latency efficiency: randomized, adaptive, self-configuring cluster formation and localized control for data transfers.

Ye et al. [5,6], Energy Efficient Clustering Scheme (EECS), proposed by Ye et al. [5,6], was a clustering algorithm which better suits the periodical data gathering applications. EECS was a LEACH-like scheme, where the network was partitioned into several clusters and single-hop communication between the cluster head (CH) and the base station was performed.

Li et al.[7]. Energy-Efficient Uneven Clustering (EEUC) algorithm, proposed by Li et al. [7], was a distributed competitive and clustering algorithm, where cluster heads (CHs) are elected by confined competition, which was not like LEACH. Each node has a pre-assigned viable range, which was smaller as it gets close to the BS.

Chan and Perrig et al[8]. Algorithm for Cluster Establishment (ACE) [8], given by Chan and Perrig, employs an emergent algorithm, which was any calculation that achieves formally or stochastically probable global effects, by communicating directly with only a bounded number of instant neighbors and without the use of central control or global visibility.

Muruganathan et al[9], Base-Station Controlled Dynamic Clustering Protocol (BCDCP), introduced by Muruganathan et al. [9], was a centralized clustering routing protocol with the base station capable of difficult computation. The main idea of BCDCP was the cluster formation where each cluster head (CH) serves an almost equal number of MNs to balance cluster head (CH) overload and uniform cluster head (CH) placement throughout the network.

Lindsey et al[10], Power-Efficient Gathering in Sensor Information Systems (PEGASIS), proposed by Lindsey et al. [10], was an improvement of LEACH. The main idea of PEGASIS was for each node to only communicate with their close neighbors and take turns being the leader for transmission to the sink.

Anjeshwar and Agrawal et al[11], Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [11], proposed by Anjeshwar and Agrawal, was a hierarchical protocol whose main goal was to cope with sudden changes in the sensed attributes such as temperature.

Manjeshwar and Agrawal et al[12], The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [12], introduced by Manjeshwar and Agrawal, was an extension to TEEN and aims at both transmitting periodic data and reacting to time critical events.

Luo et al. [13], The Two-Tier Data Dissemination (TTDD) approach, presented by Luo et al. [13], was a low-power protocol for efficient data delivery from multiple sources to multiple mobile sinks. It exploits a geographic routing based on grid of cells as the routing method.

Ramakant et al. [14] presented an efficient technique for clustering of sensor node in the WSNs. In the existing LEACH protocol the clusters are formed using the distance calculation from the node to cluster head. But for a network to be good designed there should be a better cluster formation.

III. PROPOSED WORK

3.1 Problem Definition
A wireless sensor network is an autonomous system of sensor nodes. It has a Base Station and sensor nodes. Sensor nodes collect data from their environment and send it to the Base Station. Heterogeneous sensor network contains high energy sensor nodes as well as low energy nodes. A single-tier network can cause the gateway to overload with the increase in sensors density. Such overload might cause latency in communication and inadequate tracking of events. In addition, the single-tier architecture is not scalable for a larger set of sensors covering a wider area of interest because the sensors are typically not capable of long-haul communication.

3.2 Need and significance of proposed research work
Each cluster consists of a cluster head and several member nodes. The member nodes collect data and send it to their cluster heads. The cluster head aggregates and transmits the data to the Base Station. The energy consumption of cluster heads is higher than that for member nodes. A clustering
protocol is required which can distribute energy in an efficient manner. A protocol is required which can utilize heterogeneity in a sensor network to extend its (i) lifetime and (ii) throughput by electing better cluster heads in a proficient manner.

3.3 Objectives
In this research we study few of clustering Routing techniques in WSN. The summarized of goal of work for the dissertation as follows.
- To study the existing techniques of clustering in Wireless Sensor Networks.
- To propose and implement energy efficient based method for clustering.
- To compare the existing technique with the proposed technique using the parameter Energy Consumption per Round.

3.4. Research Methodology
In hierarchical architectures, the nodes are divided into clusters and a set of nodes is periodically elected as a CH. cluster heads (CHs) are used for more complex tasks, such as: the management of each cluster, collecting data from non-CHs, data aggregation, and sending the collected data to the BS. In this context, it is important to use multiple metrics for cluster head (CH) election to provide an energy-efficient and load balance model. Furthermore, the cluster formation process can lead to poor energy use, if the cluster heads (CHs) that are elected are only based on a single metric. In this context, CLENER [19] proposes an equation, which is used by nodes to enable them to become a CH.

3.4.1 Cluster head (CH) election
During the initialization of the network, base station broadcasts a startup message, which enables the node to compute the distance to BS. Following this, the nodes are able to adjust the transmission power according to distance, which reduces the energy consumption since higher transmission power consumes more energy.

After adjusting the transmission power, each node generates a random number (μ), which ranges from 0 to 1. Then, the node decides to become a cluster head (CH) by comparing μ with the T(n), which is computed by means of Equation 1. If μ is less than T(n), the node becomes a cluster head (CH) for the current round.

\[ T(n) = \frac{\eta}{1 - p \left(\frac{\text{RE}}{\sigma_{re}}\right)} + \alpha \left(1 - e^{-\frac{\text{RE}}{\sigma_{re}}}\right) \]  

Where η and α are weights to give importance, the sum is exactly 1. The Residual Energy is denoted as \( \text{RE} \), and \( \sigma_{re} \) means the energy variance, which is used to produce better cluster head (CH) candidates.

Equation 1 uses a gauss function, due to the fact that has better result in terms of energy efficiency and representation in the context of an imprecise environment.

Now, the node that becomes cluster head (CH) broadcasts a cluster head (CH) message, which contains the value of its remaining energy. Then, cluster head (CH) waits for a join message from the non-CH nodes. However, if the cluster heads (CHs) do not receive a join message, this cluster head (CH) should not become CH.

3.4.2 Cluster Formation
In present work author had used three linguistic input variables of the system are the remaining energy which can be expressed in percentages, the distance between non-CH and cluster head (CH) (expressed in meters) and the distance between cluster head (CH) and Base Station (expressed in meters). The specifications related for the input and output functions of the system and their respective Linguistic Values (LV) are as follows:
- Residual energy: \( u = [0,100] \): LV = low, average, high;
- Distance: \( u = [0,100] \): LV = small, average, big;
Probability: \( u = (0,1] \): \( LV = \) very high, Medium high, high, moderately medium, fairly medium, medium, moderately low, low, very low.

For the representation of the linguistic states (low, high, small and large) of the input variables, the degrees of membership to these sets must remain constant for certain values of the universe of discourse.

### 3.4 Design & Implementation

For the representation of the linguistic states (low, high, small and large) of the input variables, the degrees of membership to these sets must remain constant for certain values of the universe of discourse.

The membership functions designed for the system are shown in figure 3.1. The rules are expressed as logical implications in the form of IF-THEN statements in a mapping from fuzzy input sets to output functions.

![Figure 3.1: Membership Functions](image)

The rules are determined on the basis of an analysis of the whole network behavior through extensive simulations over time. They result in a class of higher probability, ensure an excellent chance these nodes will be elected, and differentiate depending on their distance from each CH.

Table 3.1 shows the fuzzy inference rules used in the system.

<table>
<thead>
<tr>
<th>Energy</th>
<th>Distance</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>small</td>
<td>very high</td>
</tr>
<tr>
<td>high</td>
<td>average</td>
<td>high</td>
</tr>
<tr>
<td>high</td>
<td>big</td>
<td>moderately high</td>
</tr>
<tr>
<td>average</td>
<td>small</td>
<td>fairly high</td>
</tr>
<tr>
<td>average</td>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>average</td>
<td>big</td>
<td>fairly low</td>
</tr>
<tr>
<td>low</td>
<td>high</td>
<td>moderately low</td>
</tr>
<tr>
<td>low</td>
<td>average</td>
<td>low</td>
</tr>
<tr>
<td>low</td>
<td>low</td>
<td>very low</td>
</tr>
</tbody>
</table>

The use of fuzzy logic is appropriate, whenever it is not possible to employ a mathematical model for the system. Additionally, fuzzy can reduce the complexity of the model, computational effort and memory TS receive context information from nodes as input and converts into fuzzy linguistic variable input.

The Flow Chart of the proposed model is given in figure 3.2.
RESULTS

4.1 Simulation Scenario
Initially there is a network in which 100 nodes are distributed randomly as shown in figure 4.1. New scheme is implemented in which cluster head are elected based on the given logic of presented model. These cluster head are shown by star shape in blue color (*).

Each Normal node will elect its cluster head based on Probability which can be calculated Fuzzy Logic System using the two input variables “distance between the node & cluster head” and “Residual Energy”. Figure 4.2 and figure 4.3 show both inputs and their corresponding graphical representation in fuzzy system.
Correlation between Residual energy and Distance for Fuzzy system is shown in figure 4.4.

Finally figure 4.5 shows the surface graph for probability calculation for cluster formation.

Using this Probability Calculation fuzzy logic, each normal node calculates the probability for each cluster head. The node which has the highest probability with respect to any cluster head will be the member of that cluster for cluster head in that round. In this way Cluster formation is done in the presented work.
4.2 Performance Evaluation

The basic parameters used for simulations are listed in table 4.1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Size</td>
<td>50m X 50m</td>
</tr>
<tr>
<td>Location of Base Station</td>
<td>25m X 25m</td>
</tr>
<tr>
<td>No. of Nodes</td>
<td>100</td>
</tr>
<tr>
<td>Probability of cluster</td>
<td>0.1</td>
</tr>
<tr>
<td>Initial Energy of sensor node</td>
<td>20 J</td>
</tr>
<tr>
<td>The Data packet Size</td>
<td>4000 bits</td>
</tr>
<tr>
<td>DeltaT</td>
<td>10</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.6</td>
</tr>
<tr>
<td>$E_{fs}$</td>
<td>10 J/bit/m$^2$</td>
</tr>
<tr>
<td>$E_{mp}$</td>
<td>0.0013 J/bit/m$^4$</td>
</tr>
</tbody>
</table>

Based on these parameters author will carry out the simulations. These parameters are taken after studying different research papers used in Wireless sensor network.

Figure 4.6 shows the energy consumed by old scheme in the given 10 rounds.

![Figure 4.6: Energy Consumption in old scheme](image)

Figure 4.7 shows the energy consumed by new scheme in the given 10 rounds.

![Figure 4.7: Energy Consumption in New Scheme](image)

Figure 4.8 shows the comparison of energy consumed by both old scheme and new scheme. It shows that the new scheme is more energy efficient than the traditional old scheme.
Table 4.2 is showing the average energy consumption of old and proposed scheme which gives the results that proposed scheme is consuming almost 50% (Approx.) less energy as compared to old scheme. Also, the standard deviation for energy consumption of proposed scheme is 30% (approx.) less.

Table 4.2: Comparison of Energy Consumption & Standard Deviation

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Round no.</th>
<th>Energy (%</th>
<th>Energy consumption (%)</th>
<th>Difference in Energy consumption (%)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old</td>
<td>1</td>
<td>99.96</td>
<td>0.34</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>99.62</td>
<td>188.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposed</td>
<td>1</td>
<td>99.95</td>
<td>0.18</td>
<td>0.074</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>99.77</td>
<td></td>
<td></td>
<td>0.074</td>
</tr>
</tbody>
</table>

V. CONCLUSION & FUTURE SCOPE

5.1 Conclusion
In New scheme fuzzy logic is used in which non-CHs select the best cluster head (CH) by considering residual energy of cluster head (CH) and a distance from non-CH to Base Station (Sink). The use of fuzzy logic is suitable, whenever it is not possible to use a mathematical model for the system. Additionally, fuzzy can reduce the complexity of the model, computational effort and memory. Energy consumption is affected by message communication between nodes, so our technique is efficient than traditional old scheme.

5.2 Future Work
A further direction of this study can be that the chosen cluster head should be given an extra amount of energy at the time when it will get selected as cluster head. It is for long life of cluster head and Network.

REFERENCES


