**LEACH protocol using Fuzzy Logic**

**5.1 Introduction**

The energy supply of the sensor nodes is one of the main constraints in the design of wireless sensor network. The energy consumption can be reduced by allowing only some nodes to communicate with the base station. These nodes called cluster-heads collect the data sent by each node in that cluster compressing it and then transmitting the aggregated data to the base station. Appropriate cluster-head selection can significantly reduce energy consumption and enhance the lifetime of the WSN.

A fuzzy logic approach to cluster-head election is proposed based on three descriptors - energy, concentration and centrality [16]. Simulation shows that depending upon network configuration a substantial increase in network lifetime can be accomplished as compared to probabilistically selecting the nodes as cluster-heads using only local information. For a cluster, the node elected by the base station is the node having the maximum chance to become the cluster-head using three fuzzy descriptors-node concentration, energy level in each node and node centrality with respect to the entire cluster, minimizing energy consumption for all nodes consequently increasing the lifetime of the network.

Fuzzy logic control is capable of making real time decisions, even with incomplete information. Conventional control systems rely on an accurate representation of the environment, which generally does not exist in reality. Fuzzy logic systems, which can manipulate the linguistic rules in a natural way, are hence suitable in this respect. Moreover it can be used for context by blending different parameters - rules combined together to produce the suitable result.

Comparison with a popular cluster-head selection technique called LEACH (Low Energy Adaptive Clustering Hierarchy) is done. LEACH is based on a stochastic model and uses localized clustering. The nodes select themselves as cluster-heads without the base station processing. Other nodes in the vicinity join the closest cluster heads and transmit data to them.

**5.2 Assumptions**

For WSN scenario we make the following assumptions:

• The base station is located far from the sensor nodes and is immobile.

• All nodes in the network are homogeneous and energy constrained.

• Symmetric propagation channel.

• Base station performs the cluster-head election.

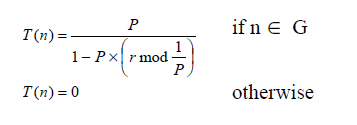
• Nodes have location information that they send to the base station with respective energy levels during set up phase.

• Nodes have little or no mobility.

**5.3 Previous Cluster Head Election Protocol**

Many proposals have been made to select cluster heads. In the case of LEACH, to become a cluster head, each node n chooses a random number between 0 and 1. If the number is less than the threshold T(n), the node becomes the cluster-head for the current round.

The Threshold is set at:



Where P is the cluster-head probability, r the number of the current round and G the set of nodes that have not been cluster-heads in the last 1/P rounds.

**5.4 Need for Fuzzy Logic**

Several disadvantages are there for selecting the cluster-head using only the local information in the nodes. Firstly, since each node probabilistically decides whether or not to become the cluster-head, there might be cases when two cluster-heads are selected in close vicinity of each other increasing the overall energy depleted in the network. Secondly, the number of cluster-head nodes generated is not fixed so in some rounds it may be more or less than the preferred value.

Thirdly, the node selected can be located near the edges of the network; wherein the other nodes will expend more energy to transmit data to that cluster-head. Fourthly, each node has to calculate the threshold and generate the random numbers in each round, consuming CPU cycles.

In a case each node calculates its distance to the area centroid which will recommend nodes close to the area centroid and not the nodes that is central to a particular cluster, cluster centroid. Thus it leads to overall high energy consumption in the network for other nodes to transmit data through the selected node.

**5.5 Fuzzy System Model**

The cluster-heads are elected by the base station in each round by calculating the chance each node has to become the cluster-head by considering three fuzzy descriptors – node concentration, energy level in each node and its centrality with respect to the entire cluster.

A central control algorithm in the base station will produce better cluster-heads since the base station has the global knowledge about the network. Moreover, base stations are many times more powerful than the sensor nodes, having sufficient memory, power and storage. In this approach energy is spent to transmit the location information of all the nodes to the base station (possibly using a GPS receiver).

Considering WSNs are meant to be deployed over a geographical area with the main purpose of sensing and gathering information, we assume that nodes have minimal mobility, thus sending the location information during the initial setup phase is sufficient. The operation of this fuzzy cluster-head election scheme is divided into two rounds each consisting of a setup and steady state phase similar to LEACH. During the setup phase the cluster-heads are determined by using fuzzy knowledge processing and then the cluster is organized. In the steady state phase the cluster-heads collect the aggregated data and performs signal processing functions to compress the data into a single signal. This composite signal is then sent to the base station.

Expert knowledge is represented based on the following three descriptors [16]:

• Node Energy - energy level available in each node, designated by the fuzzy variable energy,

• Node Concentration - number of nodes present in the vicinity, designated by the fuzzy variable concentration,

• Node Centrality - a value which classifies the nodes based on how central the node is to the cluster, designated by the fuzzy variable centrality.

**5.6 Fuzzy Rule Base**

The linguistic variables used to represent the node energy and node concentration, are divided into three levels: low, medium and high, respectively, and there are three levels to represent the node centrality: close, adequate and far, respectively. The outcome to represent the node cluster-head election chance was divided into seven levels: very small, small, rather small, medium, rather large, large, and very large.

The fuzzy rule base currently includes rules like the following: if the energy is high and the concentration is high and the centrality is close then the node’s cluster-head election chance is very large. Thus we used 33 = 27 rules for the fuzzy rule base. We used triangle membership functions to represent the fuzzy sets medium and adequate and trapezoid membership functions to represent low, high, close and far fuzzy sets. The membership functions developed and their corresponding linguistic states are represented in Table 5.1 and Figures 5.1 through 5.4



**Fig 5.1 Fuzzy set for fuzzy variable *Energy***

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**Fig 5.2 Fuzzy set for fuzzy variable *Concentration***

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**Fig 5.3 Fuzzy set for fuzzy variable *Centrality***

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**Fig 5.4 Fuzzy set for fuzzy variable *Chance***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No** | **Energy** | **Concentration** | **Centrality** | **Chance** |
| 1 | Low | Low | Close | Small |
| 2 | Low | Low | Adequate | Small |
| 3 | Low | Low | Far | Very Small |
| 4 | Low | Medium | Close | Small |
| 5 | Low | Medium | Adequate | Small |
| 6 | Low | Medium | Far | Small |
| 7 | Low | High | Close | Rather Small |
| 8 | Low | High | Adequate | Small |
| 9 | Low | High | Far | Very Small |
| 10 | Medium | Low | Close | Rather Large |
| 11 | Medium | Low | Adequate | Medium |
| 12 | Medium | Low | Far | Small |
| 13 | Medium | Medium | Close | Large |
| 14 | Medium | Medium | Adequate | Medium |
| 15 | Medium | Medium | Far | Rather Small |
| 16 | Medium | High | Close | Large |
| 17 | Medium | High | Adequate | Rather Large |
| 18 | Medium | High | Far | Rather Small |
| 19 | High | Low | Close | Rather Large |
| 20 | High | Low | Adequate | Medium |
| 21 | High | Low | Far | Rather Small |
| 22 | High | Medium | Close | Large |
| 23 | High | Medium | Adequate | Rather Large |
| 24 | High | Medium | Far | Medium |
| 25 | High | High | Close | Very Large |
| 26 | High | High | Adequate | Rather Large |
| 27 | High | High | Far | Medium |

**Table 5.1 Fuzzy Rule Base**

**5.7 Results**

We compare the LEACH algorithm with our design in the final simulation. Although LEACH does local information processing to select the cluster-head nodes, it offers a comparison platform to check for improvements. To compare with LEACH, we select the reference network consisting of 20 randomly generated nodes over an area of 100X100 meters with the cluster-head probability of 0.05. Therefore about 1 node per round becomes cluster-head, making it suitable for us to compare easily. The concentration fuzzy set is scaled accordingly, with the other parameters remaining the same as sample network 2. Both algorithms optimize the intra-cluster energy consumption and thus do not influence the energy required to transmit to the base station.

**Conclusion**

The new IEEE 802.15.4 standard, which is designed for low rate wireless personal area networks (LR-WPANs), is an enabling standard. It is the first standard to allow simple sensors and actuators to share a single standardized wireless platform.

To evaluate the general performance of this new standard, we develop an NS2 simulator, which covers all the 802.15.4 PHY and MAC primitives, and analyze various performance metrics: packet delivery ratio, hop delay, collision rate, association rate and orphaning rate. From our study we can say that packet delivery ratio decreases and hop delay increases and with increase in traffic load. Both association rate and orphaning rate decreases with increase in beacon order.

In case of the LEACH Protocol using Fuzzy Logic, Cluster-heads were elected by the base station in each round by calculating the chance each node has to become the cluster-head using three fuzzy descriptors. This approach is more suitable for electing cluster-heads for medium sized clusters. With this system model a substantial increase in the network lifetime is accomplished as compared to LEACH. By modifying the shape of each fuzzy set accurately, a further improvement in the network lifetime and energy consumption can be achieved.

Since centrality, calculated on the basis of the sum of the squared distances of other nodes from the given node, is one of the descriptors for electing suitable cluster-head, a network with biased distribution of nodes can be tested in the future with further experiments.

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