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An Intelligent Fuzzy Based Cluster Head Selection Scheme for Wireless Sensor Networks

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Abstract: Wireless Sensor Networks have a great importance in today's scenario due to its practical applications in research areas as well as in daily life. It has an inherent characteristic of limited energy resource, so main focus of researchers is to make it energy efficient with enhanced lifetime. Clustering is an important method for lesser energy dissipation by decreasing the number of messages to be sent to the sink. It involves selection of cluster head based on some parameters, and then send the aggregated message to the sink after receiving messages from the nodes in its vicinity. The criteria of cluster head selection greatly affect the efficiency of the networks. In this paper, a two level fuzzy based approach is used in cluster head selection. In first level, three parameters – energy level, neighbour density and centrality are used to find out the aggregated eligibility factor of the nodes for second level. The aggregated eligibility factor along with distance from sink and random variable are used to finally elect the cluster heads in the later level .The simulation of proposed approach in MATLAB results in decreased energy consumption with lifetime maximisation as compared to LEACH.

Keywords: Wireless sensor network, fuzzy logic, cluster head, residual energy and centrality.

1. INTRODUCTION

Wireless Sensor Networks is the emerging field of various advancements. It comprises of sensor nodes geographically distributed over an area, which sense the environmental conditions like temperature, humidity, sound, vibrations etc. and pass this information to the sink. It has its practical applications in various fields like military, health, warehouses, smart homes etc. As the sensor nodes have limited battery power, these networks have an inherent characteristic of limited energy resource. Various routing protocols and energy efficient schemes are designed for maximum utilisation of available power.

Clustering is one of the hierarchical routing techniques which are used to make the network energy efficient by using the efficient routing. Various advancements have been made further in the clustering methodology and many more are going on. In clustering schemes, there are two kinds of nodes in one cluster, one cluster head (CH) and several cluster members (CMs). Cluster members gather data from the environment periodically and send the data to cluster heads. Cluster heads aggregate the data from their cluster members, and send the aggregated data to the base station (BS) [1]. Further, cluster-based routing results in lower energy consumption within a cluster by performing data aggregation and therefore, decreasing the number of transmitted messages to the BS together with eliminating data redundancy [2].

In clustered approach, the cluster head selection technique plays an important role towards the efficiency of the network. Different network and node parameters contribute a lot in cluster head selection. LEACH, a popular hierarchical routing protocol, uses a probabilistic approach for cluster head selection. But it uses only local information to find out the probability of the nodes to be a cluster head. In further advancements various parameters have also been considered, like in HEED, residual energy is considered to find out the probability. But there are some other factors also that affect the cluster heads and hence the overall efficiency of the network. Further researches and advancements have considered various optimization techniques with different parameters for better cluster head selection.

In this paper, a two level fuzzy based cluster head selection technique is proposed by considering different node and network parameters in each level. The simulation results of proposed method shows that this approach results in lesser energy dissipation and improved network lifetime in comparison with LEACH.

2. RELATED WORK

Wireless Sensor Networks comprises of energy constrained sensor nodes which have limited lifetime. In the field of sensor networks, the main focus of researchers is to obtain optimum utilisation of energy. Several strategies, approaches and algorithms have been proposed to achieve the same.

LEACH is an efficient clustering protocol that was proposed quite earlier. It created a strong foundation for many other algorithms for further improvements such as those proposed by the authors of [3], [4] and [5] and many more. In addition, it was the most important protocol that proposed to increase the overall lifetime of the network and to decrease the overall energy consumed by the network [6]. The operation in LEACH is divided into rounds. Each round contains a

set-up stage, where each sensor node picks a random number between 0 and 1 to decide whether it will become a cluster-head or not. If the number chosen by a particular node is less than the threshold value $T(n)$, the node becomes a CH for the current round. In LEACH, several disadvantages are there for selecting the cluster-head using only the local information in the nodes.

A lot of research has already done for cluster head selection in fuzzy environment to make improvements over LEACH. In paper [7], two strong parameters – energy and centrality have been used to elect cluster head which improves lifetime by a significant amount. In paper [8], three parameters have been considered i.e. - residual energy, number of neighbours and distance in fuzzy environment to decide the cluster heads. In [9], fuzzy is applied on different parameter set – residual energy, node centrality and neighbour density to find out the chance of being cluster head.

In [10] a new cluster-head selection scheme "Cluster Head Election using Fuzzy logic" (CHEF) is introduced in which the collecting and calculating overheads is reduced by using fuzzy logic. CHEF is about 22.7% more efficient than LEACH. In [11], the sensor networks are made efficient by cluster formation using fuzzy logic with three parameters – energy level, distance to base station, distance to cluster head. In [12] a two-level fuzzy logic is used to evaluate the probability of sensor node to elect as a cluster head. In the preliminary level, node's residual energy and number of neighbours are used as parameter to decide node as cluster-head. In the advanced level, node's overall cooperation to the whole network is considered with three fuzzy parameters. These parameters are centrality, proximity to base station and distance between cluster heads. This proposed approach consumes less energy and improve the life time of network over LEACH.

As the performance of LEACH is based on the random parameter means randomisation play an important role in cluster head selection hence in the efficiency of the networks. In our proposed scheme, five parameters affecting the cluster head and one random parameter are taken in dual stages to finally elect the cluster heads.

3. SYSTEM MODEL

The system model will consists of randomly deployed sensor nodes over a geographical area which senses the environmental conditions like temperature, humidity etc., assuming that nodes are stationary once deployed and clusters will be formed to commence the operation. The overall functioning of clusters is controlled by cluster heads. The whole operation is broken up into rounds, where each round begins with a setup phase in which cluster head selection takes place followed by cluster formation. Cluster heads are elected by dual stage fuzzy logic giving node and network parameters as input. This cluster head selection scheme is centralized assuming base station keeping all knowledge of the network scenario since the base station has the global knowledge about the network and are more powerful than the sensor nodes, having sufficient memory, power and storage. When the clusters are organized after election of cluster heads by fuzzy logic, data is transferred to the base station. In order to minimize overhead, the steady state phase is long compared to the set-up phase.

The efficiency of the cluster based networks mainly depends on how effectively the cluster heads are elected. There are various network and node parameters that affect the working of cluster head. In our proposed scheme, we have considered five network and node parameters and one random parameter in dual stage of fuzzy based cluster head selection scheme. In the first stage, the important parameters that contribute to overall efficiency are used to find out the eligibility factor of all the nodes for cluster head selection. This eligibility factor contributes in the later stage for the final selection of cluster heads. In the later stage, the eligibility factor computed in the previous stage, the distance from the base station and one random variable is used to find out the final cluster heads. This dual stage process is iterated at base station for each round of operation. The overall cluster head selection scheme is divided into two phases. First phase compute the eligibility factor of all the nodes taking the basic parameters as input and it is then passed to the second phase for final selection of cluster heads along with other parameters.

Nomination phase: The knowledge of nomination phase is represented based on the following three node parameters:

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

• Neighbour Density - number of nodes present in the neighbourhood, designated by the fuzzy variable Neighbour Density,

• Centrality - define how central the node is to the cluster, designated by the fuzzy variable *centrality*. The node centrality is computed at the base station by selecting each node and calculates the sum of the squared distances of other nodes from the selected node.

The values of input variables are divided into three levels: *low*, *average* and *high*, respectively, and there are three levels to represent the eligibility factor: *less*, *medium* and *large*, respectively. We have used $3^3 = 27$ rules for the fuzzy rule base as there are three variables and each variable has three levels. Guassmf membership functions are used to represent all the fuzzy sets. The Mamdani FIS is used because of its simplicity in use.

TABLE 1: Rule Base of Nomination Phase

Energy Level	*Neighbour Density*	*Centrality*	*Eligibility factor*
Low	Low	low	Less
Low	Low	Average	Less
Low	Low	High	Medium
Low	Average	Low	Less
Low	Average	Average	Medium
Low	Average	High	Medium

Low	High	Low	Less
Low	High	Average	Medium
Low	High	High	Medium
Average	Low	Low	Less
Average	Low	Average	Medium
Average	Low	High	Medium
Average	Average	Low	Less
Average	Average	Average	Medium
Average	Average	High	Large
Average	High	Low	Medium
Average	High	Average	Medium
Average	High	High	Large
High	Low	Low	Less
High	Low	Average	Medium
High	Low	High	Large
High	Average	Low	Medium
High	Average	Average	Medium
High	Average	High	Large
High	High	Low	Medium
High	High	Average	Large
High	High	High	Large

Election phase: This is the advanced phase for the final selection of cluster heads. In this stage, the eligibility factor and distance from base station are the main parameters which determine the probability of the nodes for the cluster head. To provide uniformity among the nodes in the cluster head selection, one random variable is also used. So, as there are also three variables with each variable having three levels, there are 27 rules in the rule base. The following table shows the rule base of this phase.

TABLE 1: Rule Base of Election Phase

Eligibility factor	*Distance from Sink*	*Random Number*	*Probability*
Low	Low	Less	Less
Low	Low	Average	Less
Low	Low	High	Medium
Low	Average	Less	Less
Low	Average	Average	Medium
Low	Average	High	Medium
Low	High	Less	Less
Low	High	Average	Medium
Low	High	High	Medium
Average	Low	Less	Less
Average	Low	Average	Medium
Average	Low	High	Medium
Average	Average	Less	Less
Average	Average	Average	Medium
Average	Average	High	Large
Average	High	Less	Medium
Average	High	Average	Medium
Average	High	High	Large
High	Low	Less	Less
High	Low	Average	Medium
High	Low	High	Large
High	Average	Less	Medium
High	Average	Average	Medium
High	Average	High	Large
High	High	Less	Medium
High	High	Average	Large
High	High	High	Large

4. SIMULATION RESULTS

To simulate the scheme using MATLAB, we have the taken the network area of 200 × 200 m^2 with a total number of 100 nodes deployed in it. The initial energy of nodes is assumed to be 0.5J. The location of the sink is taken at (200,100). We

have analysed the results taking four parameters and their variance with number of rounds. The resultant graphs have been compared with the outcomes of LEACH. The graphs have shown the simulation results after running the protocol for approximately 1000 rounds. The lifetime has been analysed in terms of number of nodes alive per round and orphan nodes per round. The energy dissipated per node per round tells how much the network efficient towards energy consumption. The following graphs show the comparative results of Fuzzy protocol with LEACH.

Figure 1 shows that fuzzy based scheme results in more number of nodes alive over LEACH after 1000 rounds illustrating better lifetime. Moreover, figure 4 shows that our proposed model also generates average less number of orphan nodes achieving better coverage of the area. Figure 3 results in comparative less energy usage with uniform number of clusters formed as given by figure 2.

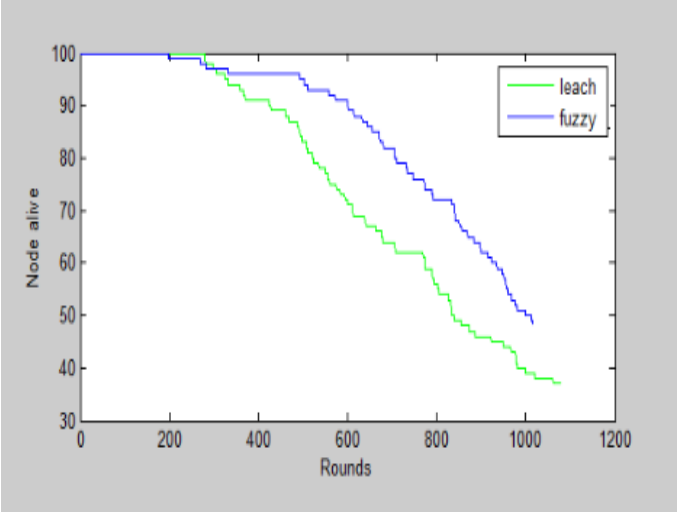

Fig. 1 A graph between number of nodes alive per round

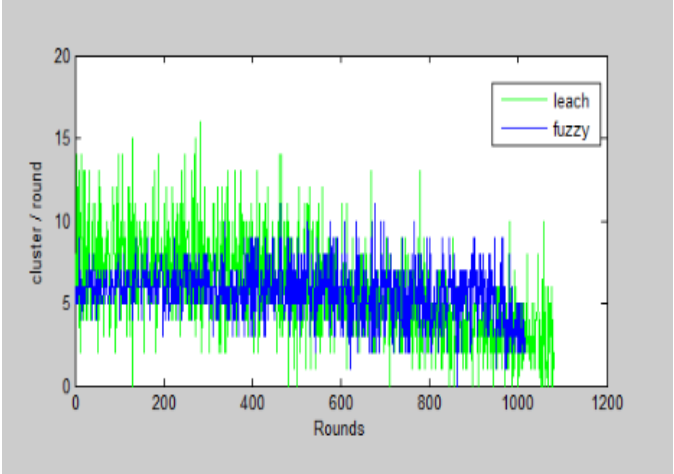

Fig. 2 A graph of number of clusters formed per round

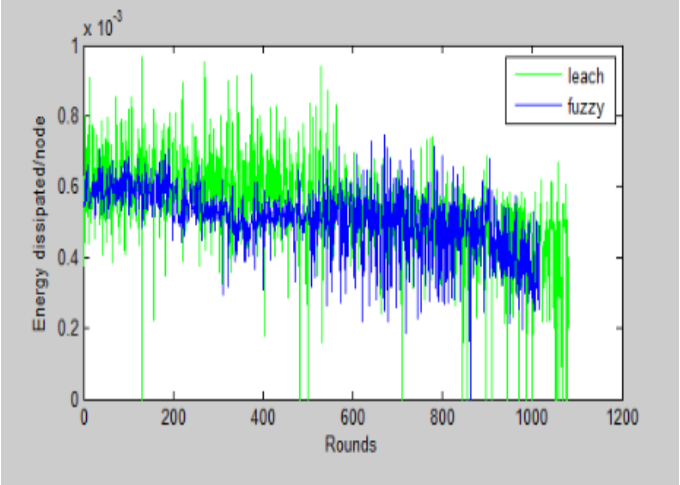

Fig. 3 A graph of energy dissipated per node per round

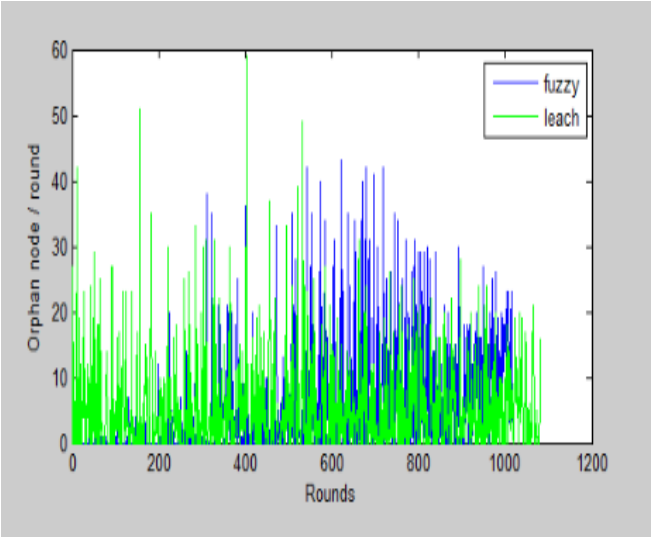

Fig. 4 A graph of number of orphan nodes per round

5. CONCLUSION AND FUTURE SCOPE

The graphical results of the simulation of proposed system show that the model achieves better lifetime and reduced energy consumption with uniform number of clusters formed in each round in comparison with LEACH. The model can be enhanced further by incorporating various important parameters related to security, Quality of Service etc. It can be further analyzed considering the mobility of the nodes to achieve more practical and application specific results.

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