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Genetically Optimized Clustering Probability and Fuzzy Logic Based Clustering Approach in Wireless Sensor Network

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Abstract – **Sensor nodes in WSN are powered by a battery. Sensor nodes consume the battery power mainly in the tasks like data transmission, data reception, and sensing. Sometimes it is impractical to replace a battery in WSN because humans can't reach. Therefore once energy or computational resources are consumed, immediate recovery of these resources is a complex task so it is necessary to make use of battery power efficiently to increase the lifetime of the sensor nodes that will also increase the lifetime of the whole network.**

To make WSN energy efficient and to increase the lifetime of the network we design a Fuzzy Logic based clustering approach in a heterogeneous environment. Genetically optimized clustering probability is also proposed so as to find a method which increases the lifetime and reduces the energy consumption of the network. The execution and demonstration of this work are performed with the help of MATLAB 2014a. The performance comparison metrics are; network lifetime, network throughput and number of alive nodes.

Keywords –**Fuzzy Inference Systems, Fuzzy Logic, Genetic Algorithm, LEACH, WSN.**

I. Introduction

Wireless sensor Network have stirred up the world of wireless communications. Figure 1 shows a WSN which uses high-frequency radio waves rather than wires to communicate between nodes, is another option for home or business networking [1]. Individuals and organizations can use this option to expand their existing wired network or to go completely wireless. Wireless allows for devices to be shared without networking cable which increases mobility but decreases range.

There are two main types of wireless networking; peer to peer or ad-hoc and infrastructure. An ad-hoc or peer-to-peer wireless network consists of a number of computers each equipped with a wireless networking interface card [2]. Each computer can communicate directly with all of the other wireless enabled computers. An infrastructure wireless network consists of an access point or a base station. In this type of network the access point acts like a hub, providing connectivity for the wireless computers.

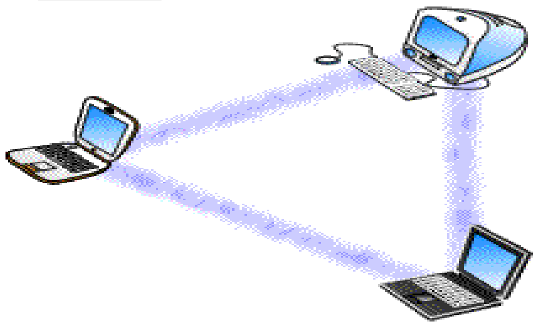

Figure 1: Wireless Network [3]

Wireless Sensor Networks (WSNs) have emerged in the last few years providing a rich set of environmental information with a wide variety of useful applications. Hierarchical routing is to efficiently maintain the energy consumption of sensor nodes [4]; by involving them in multihop communication within a particular cluster [5]; and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink [6] [7]. The research work has shown that the sensor networks that consist of identical sensors with equal capacity of sensing, computation, communication, and power is termed as Homogeneous. And if more than one type of sensors are used within a same network that is termed as Heterogeneous.

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II. Problem Definition

This section describes the problem statement, which consists of deploying a wireless network that allows us to maximize the coverage of the different sensors for indoor environment, that is, it is an internal model in which we need to find the minimum number of active sites, so that the connection to at least a percentage P of the users is allowed. This percentage should be the maximum possible to guarantee an adequate service and be able to consider that the algorithm works in an adequate manner. In the model presented, we cannot place the access points arbitrarily, they must place feasible points, which will then be optimized to obtain a better coverage with a smaller number of them. This model is the basis for other models that seek to optimize the access points, because it does not present problems with coverage and also allows taking into account parameters such as coverage and capacity. But it should be emphasized that the allocation of channels has been neglected, assuming the use of different channels, although this parameter could be implemented without any problem in this algorithm.

For this we have used a clustering algorithm that allows us to optimize the feasible points in an appropriate manner. With this algorithm, different parameters or restrictions are played depending on the internal area where you want to implement it; In addition, the different equipment that will be used must be taken into account.

If we suppose that we have an indoor zone in which we will locate several points that will allow us to connect to different sensors, then first we must establish different feasible points considering the location of the sensors, in order to later find the points of access, which are considered as those that allow connectivity to the sensors but using a coverage radius; in addition to the capacity of them, which is limited by the number of sensors that can be reached simultaneously.

If we consider that we have N number of sensors located inside a house, and in the same way, M possible locations, that is, feasible points. The feasible points are all those places where our access points can be located, but they will not necessarily be located in those points. In addition, those sensors that are within a distance R of at least one access point will be considered as covered sensors and possible active sites, while the access points have a C capacity that allows them to attend a certain number of sensors simultaneously. All these possible variables must be taken into account when using this algorithm to obtain an adequate optimization.

III. Proposed Method

A. Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [8] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form groups of sensor nodes based on the strength of the received signal and use the local clusters heads (CHs) as routers to the sink. This will save energy because the transmissions will only be made by CHs rather than all sensor nodes. The optimal number of CHs is estimated to be 5% of the total number of nodes.

All data processing such as merge and aggregate data is local to the cluster. The CHs change randomly over time in order to balance the energy dissipation of the nodes. This decision is taken by the node by choosing a random number between 0 and 1. The node becomes a CH for the current cycle if the chosen number is less than the following threshold:

$$T(n) = \begin{cases} \frac{p}{1-p^*(r \bmod \frac{1}{p})} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

B. Genetically Optimized Cluster Head Election Probability

Let n_{alive} represents the number of alive nodes with residual energy greater then the threshold energy and p be the clusterhead election probability, then the optimum number of CH elected for a given round will be:

$$P_{opt} = n_{alive} * p \quad (2)$$

Here P_{opt} is optimized using Genetic Algorithm, which is described as:

Genetic Algorithm

It was proposed by John Holland in 1975 represents a famous evolutionary technique [9]. Genetic algorithm is inspired by biological mechanisms such as Mendel's laws and the theory of evolution proposed by Charles Darwin. It is process of finding solutions to a problem given imitates that of living beings in their evolution. It uses the same vocabulary as that of biology and classical genetics for example gene, chromosome, individual, population and generation.

A Gene: is a set of symbols representing the value of a variable. In most cases, a gene is represented by a single symbol (a bit, an integer, a real, or a character).

A Chromosome: is a set of genes, presented in a given order in a way that takes into account the constraints of the problem to be treated. For example, in the commercial traveller problem, the size of the chromosome is equal to the number of cities to travel. Its content represents the order of travel of different cities. In addition, care must be

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taken that a city (represented by a number or a character for example) should not appear in the chromosome more than once.

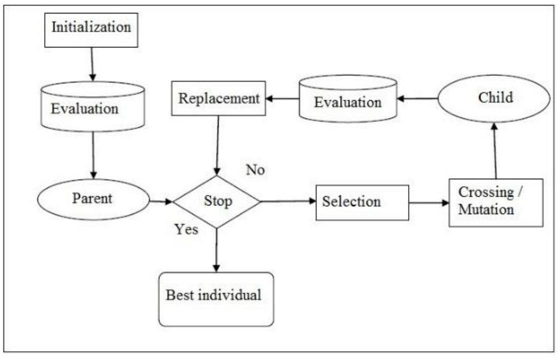

Figure 2: Approach of a genetic algorithm [9]

An Individual: is composed of one or more chromosomes. It represents a possible solution to the problem dealt with.

A Population: it is represented by a set of individuals (i.e. the set of solutions of the problem).

A generation: is a succession of iterations composed of a set of operations allowing the passage from one population to another.

Figure 2 illustrates a general diagram of the steps in the search process of the genetic algorithm.

The search process of the genetic algorithm is based on the following operators:

An Operator Coding Individuals: It allows the representation of chromosomes representing individuals.

An Operator of Initialization of the Population: It allows the production of the individuals of the initial population. Although this operator intervenes only once and at the beginning of the research, but it plays a non-negligible role in the convergence towards the global optimum. In fact, the choice of the initial population can make the search for the optimal solution of the problem treated easier and faster.

C. Selecting Cluster Heads by Fuzzy Logic in WSN

In fuzzy set theory, the fuzzy set A of X (where X is the universe of discourse) is defined as a function:

$$\mu_A(x): X \rightarrow [0, 1] \quad (2)$$

Where, $\mu_A(x) = 1$ if x is totally in A, $\mu_A(x) = 0$ if x is not in A and $0 < \mu_A(x) < 1$ if x is partially in A. The membership function is a measure:

- Degree to which an element is a member of a set;
- Degree of belonging;
- Value of belonging;
- Degree of confidence.

Fuzzy logic makes it possible to transform several real values into a few fuzzy variables with different memberships, which makes it possible to reduce the number of rules. These rules are used to control a system.

Fuzzy Inference Systems (Fuzzy Inference Systems) [10] are also known as fuzzy rule-based systems, a fuzzy model, a fuzzy expert system, and fuzzy associative memory. It is a main unit of a fuzzy logic system. Decision making is an important part of the overall system. FIS formulates the appropriate rules and on the basis of these rules the decision will be made. This is mainly based on the concepts of fuzzy set theory, fuzzy rules of the "IF-THEN" form and fuzzy reasoning [11]. An FIS uses the type declarations "IF ... THEN ..." and the connectors present in the rule declaration are "OR" or "AND" to make the decision rules necessary. In a rule, the part that follows "IF" is called the antecedent or the premise while the part that follows "THEN" is called the consequence. Basic FISs can take fuzzy inputs or digital inputs, but the outputs they produce are almost always fuzzy sets. When FIS is used as a control device, it is necessary to have a digital output. Therefore, in this case, the defuzzification method is adopted to better extract a numerical value that best represents a fuzzy set. The setting of a fuzzy system is done by experts or operators. The more complex the system, the greater the size of the rule base and the more difficult the development of fuzzy inference rules. In addition, it is sometimes impossible to obtain all the control information of the process to be regulated for various reasons, for example unreliable information or provided in digital form that cannot be translated into linguistic terms, etc. [11]. Also, because the rules correspond to empirical and non-mathematical knowledge, the fuzzy controller provides unpredictable results [11].

The FIS consists of a fuzzification interface, a rule base, a database, a decision-making unit and finally a defuzzification interface. A FIS with five functional blocks is shown in Figure 3. The function of each block is as follows:

- A rule base containing a number of fuzzy rules of type "IF-THEN";
- A database that defines the membership functions of fuzzy sets used in fuzzy rules;
- A decision unit that performs rule inference operations;
- A fuzzification interface that converts digital inputs into degrees of correspondence with linguistic values;
- A defuzzification interface that transforms the fuzzy results of the inference into a digital output that can be used later.

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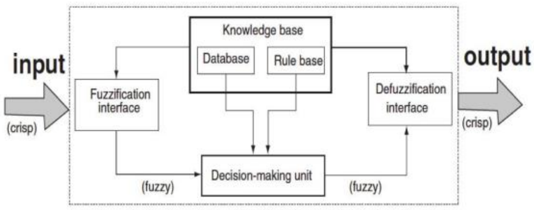

Figure 3: Fuzzy inference system [10]

The operating principle of a FIS is as follows: the digital input is converted to fuzzy using a fuzzification method. After fuzzification, a rule base will be formed. The rule base and the database are jointly designated by the knowledge base. Defuzzification is used to convert the fuzzy value to a real value that represents the output. The steps of the fuzzy reasoning (fuzzy inference operations on "IF-THEN" type rules) performed by a FIS are:

- Compare the input variables with the membership functions on the "antecedent" part in order to obtain the membership values of each linguistic label. This step is often called fuzzification.
- Combine (by a specific operator, usually multiplication or min) the membership values of the "premise" part to obtain the strength (weight) of each rule.
- Generate qualified consequences (either fuzzy or digital).
- Aggregate the consequences qualified to produce a digital output. This step is called defuzzification.

The most important method of fuzzy inference is that of Mamdani [12, 13], which is the most commonly seen inference method, therefore it is used in proposed research work. This method was introduced by Mamdani and Assilian in 1975. Another well-known method of inference is that of Sugeno [14, 15], also called Fuagi-Sugeno-Kang fuzzy inference method. This method was introduced by Sugeno in 1985. It is also called TS method. The main difference between the two methods mentioned above is the consequence of fuzzy rules. Fuzzy Mamdani systems use fuzzy sets as the consequence rule while fuzzy TS systems use a linear combination of input variables as the consequence rule.

The Fuzzy rules are designed as follows:

Table 1: Fuzzy Rule Set

S. N.	Residual Energy	Neighbour Index	Distance-to-BS	Output
1	Low	Low	Close	Small
2	Low	Low	Adequate	Small
3	Low	Low	Far	Small
4	Low	Med	Close	Small
5	Low	Med	Adequate	Small
6	Low	Med	Far	Small
7	Low	High	Close	Medium-Small
8	Low	High	Adequate	Small
9	Low	High	Far	Very-Small
10	Medium	Low	Close	Medium-Large
11	Medium	Low	Adequate	Medium
12	Medium	Low	Far	Small
13	Medium	Med	Close	Large
14	Medium	Med	Adequate	Medium
15	Medium	Med	Far	Medium Small
16	Medium	High	Close	Large
17	Medium	High	Adequate	Medium Large
18	Medium	High	Far	Medium Small
19	High	Low	Close	Medium Large
20	High	Low	Adequate	Medium
21	High	Low	Far	Medium Small
22	High	Med	Close	Large
23	High	Med	Adequate	Medium Large
24	High	Med	Far	Medium
25	High	High	Close	Very Large
26	High	High	Adequate	Medium Large
27	High	High	Far	Medium

IV. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

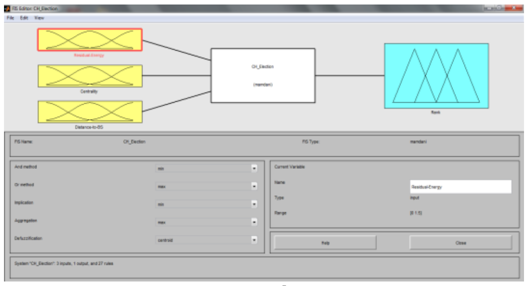

Figure 4: Proposed FIS structure

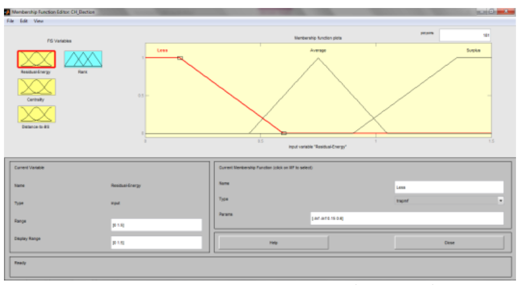

Figure 5: Graph showing membership function for input variable “Residual Energy”

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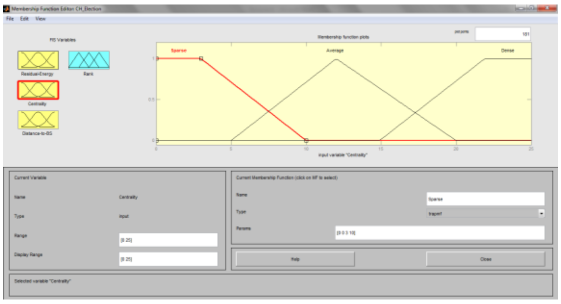

Figure 6: Graph showing membership function for input variable "Neighbourhood Index"

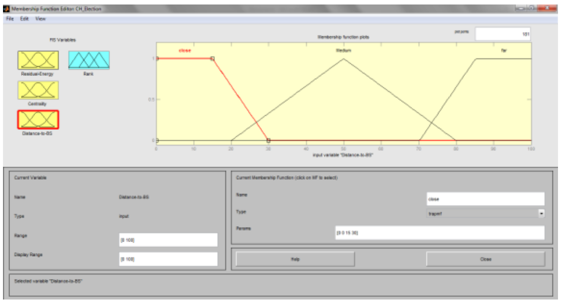

Figure 7: Graph showing membership function for input variable "Distance to BS"

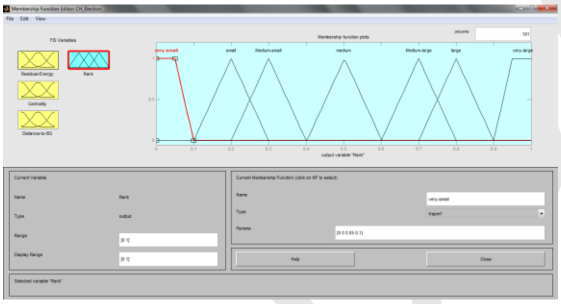

Figure 8: Membership Function plot for output

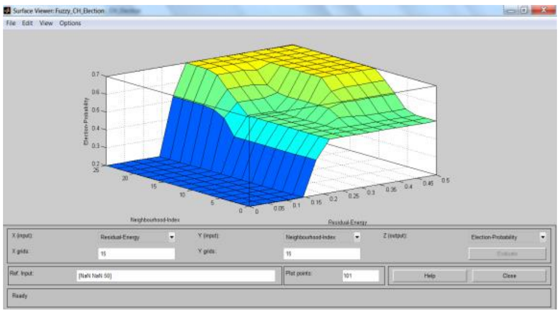

Figure 9: Graph for rule surface

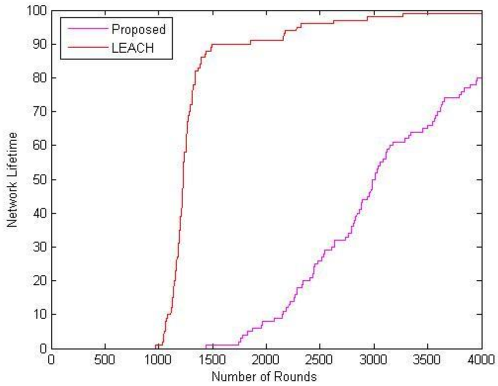

Figure 10: Network lifetime comparison for different methods

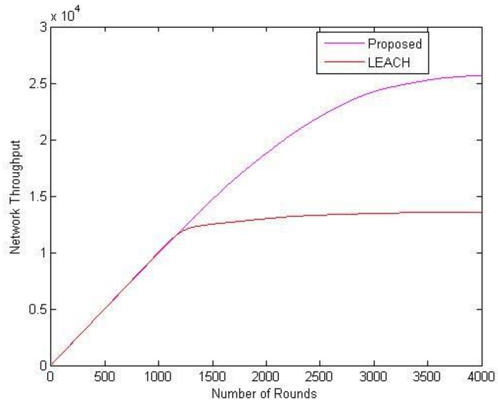

Figure 11: Network throughput comparison for different methods

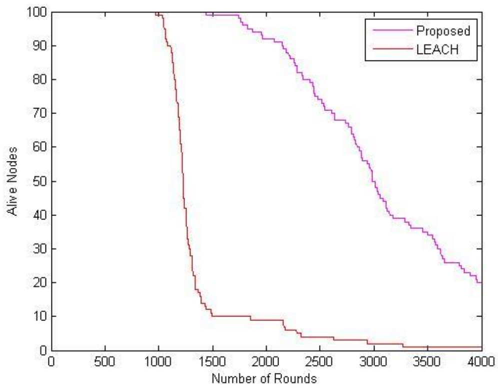

Figure 12: Comparative analysis of alive nodes for different methods

V. CONCLUSION

Under the conclusion of this work, several points were taken under consideration. For better understanding of our work that is evaluation of routing protocols for Wireless sensor network we have framed our work in two scenarios which

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consist of a simple WSN protocols, for now we have taken LEACH protocol in consideration and performed a comparative study by implementing various topologies.

Fuzzy Logic has been a famous procedure used to take care of cluster head election in WSNs because of its straightforwardness, high calibre of result, quick joining and inconsequential computational complexity.

The proposed protocol uses Genetic Algorithm to optimize the clusterhead election probability. It also proposed a fuzzy logic based approach for the selection of CHs in a WSN. This system accepts three input parameters, which are the Residual energy, centrality and distance to base station. The simulation results show that the proposed algorithm extends the network lifetime when the last node dies relative to the LEACH protocol.

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