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Fuzzy Logic based Clustering Approach in Heterogeneous and Homogeneous Wireless Sensor Networks

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Abstract – **Sensor nodes in WSN are powered with 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 heterogeneous environment so as to find a method which increases the lifetime and reduces the energy consumption of the network. The execution and demonstration of this paper is performed with the help of MATLAB 2014a. The performance comparison metrics are; network lifetime, network throughput and the number of alive nodes.**

Keywords – **Fuzzy Logic, GPS, LEACH, WSN.**

I. Introduction

Wireless Sensor Networks (WSN) is a network formed by a large number of sensor nodes where each node is equipped with a sensor to detect physical phenomena such as light, heat, pressure, etc. WSNs are considered a revolutionary method of gathering information to build the information and communication system that will greatly improve the reliability and efficiency of infrastructure systems [1].

Each node in a wireless sensor network (WSN) is resource constrained: node have limited power, speed of processing, capacity to store data, and communication bandwidth [2]. After their deployment in the target area they are responsible for self- organizing an appropriate network infrastructure. Global Positioning System (GPS) and local positioning algorithms are used to obtain location of the sensor nodes [3].

Wireless Sensor Network nodes are densely deployed in the target area and the power is provided to them via battery which is the only source of energy for most of the sensor nodes [4]. Sometimes this target area is not reachable by the humans so it is impractical to replace a battery therefore once energy or computational resources are consumed, immediate recovery of these resources is a complex task. This is the reason why a large part of the research in WSN focuses on the development of energy efficient or economical method for WSN [5]. The energy efficient nature, data aggregation, load balancing, and improved network lifetime of hierarchical cluster based routing motivate us to use them for this research. These protocols are centralized or distributed depends on the process of selecting cluster heads. The location of each and every node in the cluster and their residual energy are used to make decision for selecting one of them as a cluster head one such protocol is LEACH. The LEACH protocol is chain based protocol in which each node communicates only with its previous and next neighbour and reduces the number of communicating nodes which helps in reducing energy consumption.

Although there is a drawback of using fixed cluster head because all the data of member nodes are routed through the cluster head which lead to higher energy consumption at cluster head and due to this reason they die soon but it will also improve the life time of the network. Increasing the size of cluster head or providing more power as compared to the member node will increase their lifetime. Hence to increase the lifetime of the network and to make it energy efficient the best approach is hierarchical based clustering.

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In LEACH protocol, the cluster head are elected randomly. Therefore we have proposed a Fuzzy logic based cluster head election protocol. In this approach, parameters based cluster head election is done that increases the lifetime of the network.

This paper proposes a Fuzzy Logic based clustering approach in heterogeneous environment, so as to find a method which increases the lifetime and reduces the energy consumption of the network.

II. Proposed Methodology

A. Low-Energy Adaptive Clustering Hierarchy (LEACH)

During the configuration phase, randomly generated cluster head, the random number is selected in a range between 0 and 1 in each sensor node, if the selected number is smaller than some threshold $T(n)$, then the node is selected as the head of the cluster. Formulas of $T(n)$ as follows [6]:

$$T(n) - \int_0^n \frac{p}{1-p\left[r \; mod \left(\frac{1}{p}\right)\right]} \text{ with } n \in G \quad (1)$$

Where, p is the percentage of the number of cluster headers and the total number of nodes in the network, r is the number of the current round, G is the set of cluster nodes except the cluster head of the last rounds $\frac{1}{p}$. Then, the header node of the cluster transmits the message that it is becoming a cluster head in the entire network, each node decides to join that cluster according to the intensity of the received information and responds to the corresponding cluster header. Then, in the next phase, each node uses the TDMA method to transmit data to the cluster header node, the cluster head sends the fusion data to the receiving node. Among the clusters, each cluster competes with the communication channel with the CDMA protocol. After a period of stable phase, the network enters the next round of the cycle again, continuous cycle.

The randomly selected group header method avoids excessive power consumption, improves network life, data fusion reduces traffic effectively, but the protocol still uses jump communication, although the transmission delay it is small, the nodes require high power communications, the expansion is deficient, it is not suitable for large scale networks; even in smaller networks, the nodes furthest from the receiving node communicating with each other at high power can lead to a shorter survival time; frequent selection of the cluster head will lead to the cost of energy traffic.

B. Selecting Cluster Heads by Fuzzy Logic in WSN

Fuzzy logic was proposed in 1965 by Lotfi A. Zadeh, a professor of computer science at the University of California at Berkeley [7]. Fundamentally, fuzzy logic is a multi-valued logic, which allows intermediate values to be defined by conventional evaluations as true / false, yes / no, up / down, and so on. Concepts such as "big enough" or "very fast" can be mathematically formulated and processed by computers in order to apply thought in computer programming more humanely [8]. A fuzzy system is an alternative to the traditional notions of belonging sets and logic that has its origins in ancient Greek philosophy. The accuracy of mathematics owes its success largely to the efforts of Aristotle and the philosophers who preceded it. In their efforts to develop a concise theory of logic, and later mathematics, the so-called "laws of thought" were posited. One of them, the "Law of the excluded third", states that any proposition must be either true or false. Even when Parminedes proposed the first version of this law, there were strong and immediate objections. For example, Heraclitus proposed that things can be simultaneously true and not true. It was Plato who laid the groundwork for what would become the fuzzy logic, indicating that there was a third region (beyond the real or false). Other, more modern philosophers have echoed his feelings, including Hegel, Marx, and Engels. But it was Lukasiewicz who first proposed a systematic alternative to the bi-valued logic of Aristotle. Even at the present time, some Greek philosophers are still outstanding examples of irritability and lack of clarity (the connection to logic has been lost somewhere in the last two millenniums). Fuzzy logic has emerged as a cost-effective tool for controlling and controlling complex industrial systems and processes, for households and entertainment electronics as well as for other expert systems and applications such as SAR data classification.

1) Fuzzy Sets

In fuzzy logic, a fuzzy set contains several values. The fuzzy set is concerned with a degree of belonging (or degree of truth). A continuum of logical values is used between 0 (completely false) and 1 (completely true). A membership function is used to map an element X in the domain of real numbers to an interval of 0 to 1, which allows a degree of truth [8].

Set membership represents a value between 0 and 1. A fuzzy set can be defined as a set with fuzzy boundaries. A fuzzy set is defined as follows: let S be a set and x a member of this set. A fuzzy subset F of S is defined by a membership function $\mu_F(x)$ which measures the degree to which x belongs to F. To clarify things, let's take the following example: Let S be a set of positive integers and F a fuzzy subset of small integers. Integers can have a

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probability distribution that indicates their membership in the fuzzy subset F: $\mu_F(1) = 1.0$, $\mu_F(2) = 1.0$, $\mu_F(2) = 0.9$,. . . $\mu_F(30) = 0.01$. Figure 1 shows this membership function.

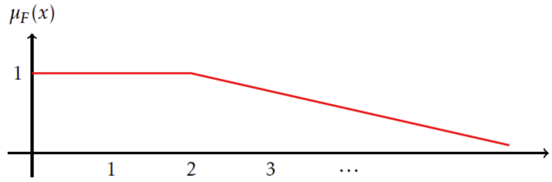

Figure 1: Representation of the fuzzy subset F of small integers [8]

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

$$\mu_A(x): X \rightarrow [0, 1] \tag{4.2}$$

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.

2) *Fuzzy Inference Systems (FIS)*

Fuzzy Inference Systems (Fuzzy Inference Systems) [9] 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 [8]. 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. [8]. Also, because the rules correspond to empirical and non-mathematical knowledge, the fuzzy controller provides unpredictable results [8]. A FIS with five functional blocks is shown in Figure 2. 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.

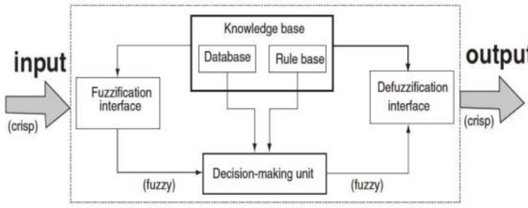

Figure 2 Fuzzy inference system [10]

3) *Fuzzy Inference Methods*

Fuzzy Mamdani systems [10, 11] 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

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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

III. Simulation Results

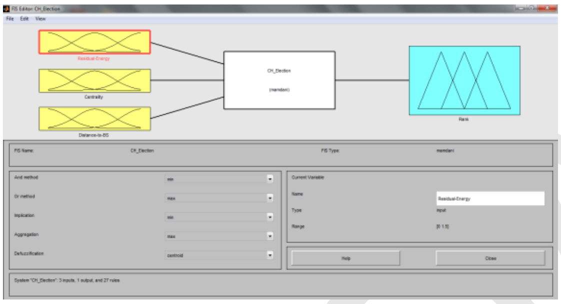

Figure 3: Proposed FIS structure

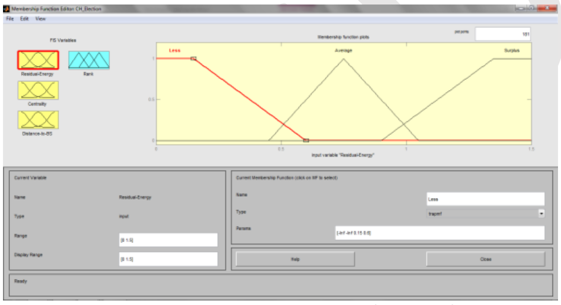

Figure 4: Graph showing membership function for input variable "Residual Energy"

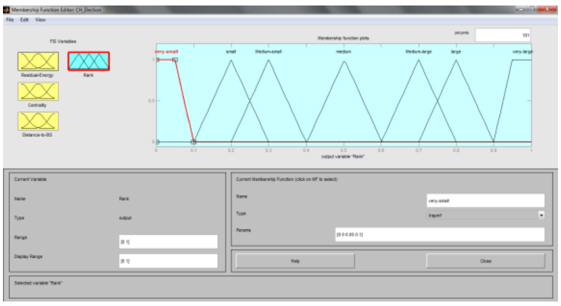

Figure 5: Membership Function plot for output

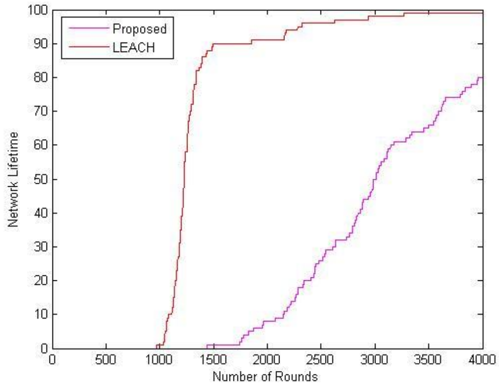

Figure 6: Network lifetime comparison for different methods

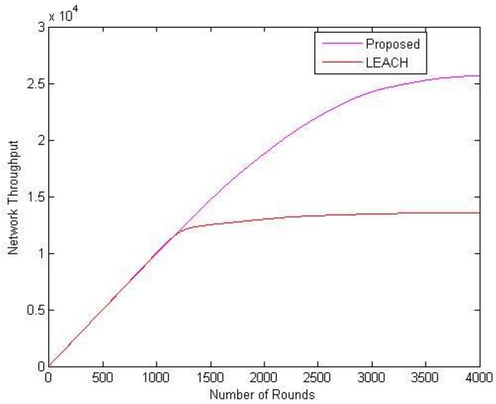

Figure 7: Network throughput comparison for different methods

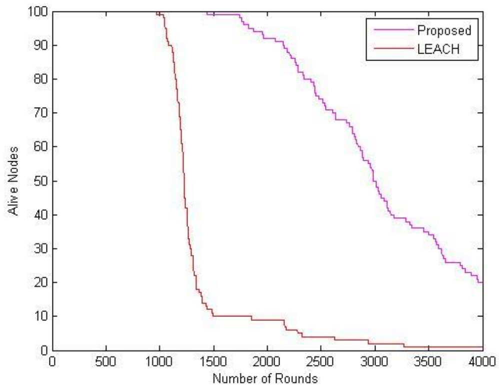

Figure 8: Comparative analysis of alive nodes for different methods

IV. Conclusion

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

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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 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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