An Efficient Approach for Clustering in Wireless Sensor Network Using Fuzzy Logic

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Abstract— **Wireless sensor network(WSN) is composed of a large number of sensor nodes that are connected to each other to perform specific tasks. These nodes have limited energy, processing power and memory. Since the network lifetime depends on the nodes On, the power supply component in the nodes is very important. Therefore we need to use strategies to reduce energy consumption in the nodes. Clustering is one of the strategies to reduce energy consumption. Many clustering algorithms have been introduced. LEACH algorithm is one of the famous of them. In this paper we proposed an efficient method for clustering using fuzzy logic with appropriate inputs and combine it with the good features of LEACH. These method is fully distributed. Therefore its speed is more and its energy consumption is less than centralized methods. Also our proposed method will resolve the weaknesses of LEACH and is more efficient than the existing methods.**

Keywords— Wireless Sensor Network, Clustering, LEACH, Fuzzy Logic, Network Lifetime Increasing

I. INTRODUCTION

In recent years, with technology development, wireless sensor networks(WSNs) have been used in various applications. WSN consist of hundreds or thousands tiny sensor nodes. These nodes are connected to each other to do a specific task or tasks[1].Each node in WSN includes components such as communication deceive(antenna) , low memory, sensor circuit (sensor temperature, light, humidity, etc.), poor processor, limited power supply, etc.

WSNs are usually used for monitoring applications and station is informed of changes in the environment. WSNs are generally used in environments where human access is difficult, such as volcanoes or military areas.

There are various challenges in wireless sensor networks because its special features. One of these challenges is the nodes limited power supply. In most cases the power supply is irreplaceable and non-rechargeable. So in WSNs must be used methods that reduce energy consumption of nodes.

The data that are sensed by nodes should be transferred to a station for processing and decision making. This station is called base-station or sink.

If each node sends its data directly to the sink a lot of energy is consumed. Since the sensed values by the close nodes are a little different, There is a possibility of redundancy in the transmitted data.

For example, two adjacent nodes data is the same and these two nodes send same data to the sink. Generally to reduce energy consumption in the network, just some of the nodes send the data to the sink. This structure is called clustering and The nodes Linked to the sink are called cluster head. The other nodes send their data to nearest cluster head. Cluster head can be perform actions such as compression on the data sent by other nodes. Consequently, small amounts of data transmitted to the sink.

As mentioned, a lot of energy is consumption to send data to the sink. As a result cluster head nodes are faced with the challenge of fast reducing energy. As soon as the cluster head Off a part or the entire network falls of work. To avoid this issue a method is that cluster head nodes equipped with replaceable and rechargeable energy source. Another way is continuously change cluster heads among the nodes within the network to the distributed energy consumption in the network.

We use the second method in which the nodes are homogeneous. In the proposed method cluster head is selected first. Each node selects then the nearest cluster head to its own. Thus clusters are produced.

Indeed, our method is similar to LEACH [2]. Two periods of time are repeated alternately until the end of the network: Stage of cluster formation and stage of stability. In this structure, similar to LEACH, each node itself decides to be cluster head and makes other nodes aware of this issue. Selecting cluster heads in LEACH are with stochastic. While in our method cluster head is selected based on several parameters and a fuzzy system.

Because LEACH is selected cluster head only with stochastic and does not care to other parameters such as residual energy and location of nodes, does not always make the best clusters. For example, a node may be cluster head that have little energy. These node may be turned off. Or if an isolated node becomes cluster head, other nodes must spend a lot of energy for sending data to this cluster head. Nevertheless, LEACH provides well uniform distribution of cluster heads and has high performance.

We use a fuzzy system with appropriate inputs to overcome the weakness of LEACH. The inputs that we consider in the fuzzy system are: number of neighbors, centrality, energy remaining, frequency of signal received from neighbors and The number of round that the node wasn't cluster head. These parameters are not so closely related and can easily work with these heterogeneous parameters by Using fuzzy logic. Also a fuzzy system does not need much computational complexity, consequently it is suitable for WSN.

The rest of this paper is organized as follows. In the next section, we give an overview of related work and some shortcomings of stochastically selecting cluster-heads. In section 3 we give an overview of fuzzy logic. In section 3 we describe our proposed method. Simulation results is presented in section 5. Finally, section 6 concludes the paper.

II. RELATED WORKS

A typical WSN architecture is shown in fig. 1. The nodes send data to the respective cluster-heads, which in turn compresses the aggregated data and transmits it to the base station. For a WSN 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 little or no mobility.

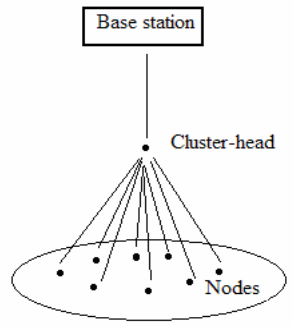


Figure 1. WSN architecture

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:

$$T(n) = p/(1-p.(r \bmod 1/p) \quad \text{if } n \in G$$
$$T(n) = 0 \quad \text{Otherwise} \tag{1}$$

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.

The method that is presented in [3] is a fuzzy approach to select cluster heads. This method is centralized and the network is aware of nodes coordinates. The decision for selecting a node as cluster head is done by the sink. This method based on three variables, node energy remaining, node concentration and centrality decides about being a node cluster head.

In [4] introduced a method called LEACH-FL. The method uses a fuzzy system with three input battery level, node density and distance from the sink, to selecting cluster heads . This method is introduced with the assumption that the network coordinates is available.

These two methods are centralized. So they are not suitable for the environments that required real-time processing. Also a lot of energy spent for sending nodes situation such as energy remaining to the sink. In these methods assumed that the network coordinates is available. For this issue, nodes need to equipped with additional hardware such as Global Positioning System (GPS). It's not possible in all environments. Another issue is that we can use inputs for fuzzy system more efficient than inputs of these methods fuzzy systems.

According to what was said, we proposed a distributed method and each node itself makes decision about being cluster head or not. This method must work in all environments and so doesn't need nodes coordinates. In this method by choosing suitable inputs for fuzzy system, is more efficient than the existence method and better cluster will be made.

III. Fuzzy Logic

Fuzzy logic (FL)is defined as the logic of human thought, which is much less rigid than the calculations computers generally perform. Fuzzy Logic offers several unique features that make it a particularly good alternative for many control problems. It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely [11, 12].

The output control is a smooth control function despite a wide range of input variations. Since, the FL controller processes user defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. Fuzzy Logic deals with the analysis of information by using fuzzy sets, each of which may represent a linguistic term like "Warm", "High", etc. Fuzzy sets are described by the range of real values over which the set is mapped, called domain, and the membership function. A membership function assigns a truth (crisp) value between 0 and 1 to each point in the fuzzy set's domain. Depending upon the shape of the membership function, various types of fuzzy sets can be used such as triangular, beta, PI, Gaussian, sigmoid, etc. We use triangular and Trapezoidal membership functions. The trapezoidal and triangular membership functions suitable for real-time operation because they don't complexity computations and also are have enough accuracy [13]. This membership functions are shown in figures 3,4.

A Fuzzy system basically consists of three parts: fuzzification, inference engine, and defuzzification. Fig. 1 shows the fuzzy system components that we use in this paper. The fuzzifier maps each crisp input value to the corresponding fuzzy sets and thus assigns it a truth value or degree of membership for each fuzzy set. The fuzzified values are processed by the inference engine, which consists of a rule base and various methods for inferring the rules. The rule base is simply a series of IF-THEN rules that relate the input fuzzy variables with the output fuzzy variables using linguistic variables, each of which is described by a fuzzy set, and fuzzy implication operators AND, OR, etc. The part of a fuzzy rule before THEN is called predicate or antecedent, while the part following THEN is referred to as consequent. The combined truth of the predicate is determined by implication rules such as MIN-MAX and bounded arithmetic sums.

The fuzzy system used in the inference engine of the expert system is the Mamdani fuzzy system. The Mamdani fuzzy system is a simple rule-base method which does not require complicated calculations and which can employ the IF…THEN… rules to control systems. Mamdani was the person who used the fuzzy method for the first time to study the process of controlling steam machine. Since then, this method has been in use and has acquired a special status[7]. All the rules in the rule-base are processed in a parallel manner by the fuzzy inference engine. Any rule that fires contributes to the final fuzzy solution space. The inference rules govern the manner in which the consequent fuzzy sets are copied to the final fuzzy solution space. Example, techniques are MIN-MAX and fuzzy adaptive method.

The defuzzifier performs defuzzification on the fuzzy solution space. That is, it finds a single crisp output value from the solution fuzzy space. Some of common defuzzification techniques are: Center of Area (COA), Center Of Gravity (COG), Extended Center of Area (ECOA), Mean of Maxima (MeOM) and etc. In this paper we use COA method for defuzzification[8].

IV. Proposed Method

We use following(see fig. 2) fuzzy system in the proposed method.

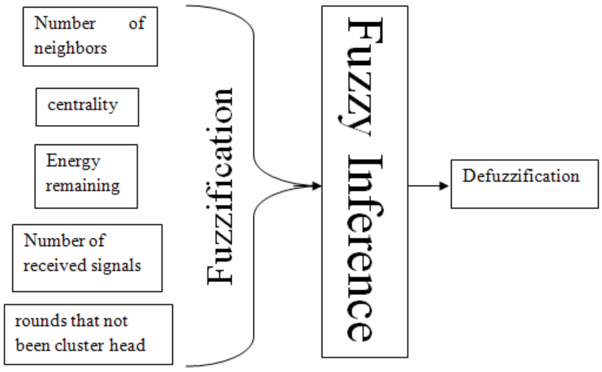


Figure 2. fuzzy system components

The fuzzy system inputs are crisp numbers that converted to the fuzzy values by membership functions. The nodes simply determine these input values. The nodes is aware of Neighboring nodes and their distance, As soon as one sending and receiving data.

This operation is done easily by using of Received Signal Strength Indication (RSSI) technique. If a node has a less distance with respect to its neighbors (centrality), other nodes will consume less energy to send data to this node. So centrality is one of the influencing parameters in the clustering. We calculate the centrality with a simple equation: Sum of mutually subtracting of distance the neighbors of the node. Whatever this number be less, node has more centrality.

If a node be in center of attention means many signals pass through it order to reach a cluster head, it is better to this node become cluster head. Also to provide distributed energy consumption the chance of a node to become cluster head increased by increasing number of rounds that node not being cluster head. Membership functions that covert crisp input values to fuzzy values are shown by fig. 3.

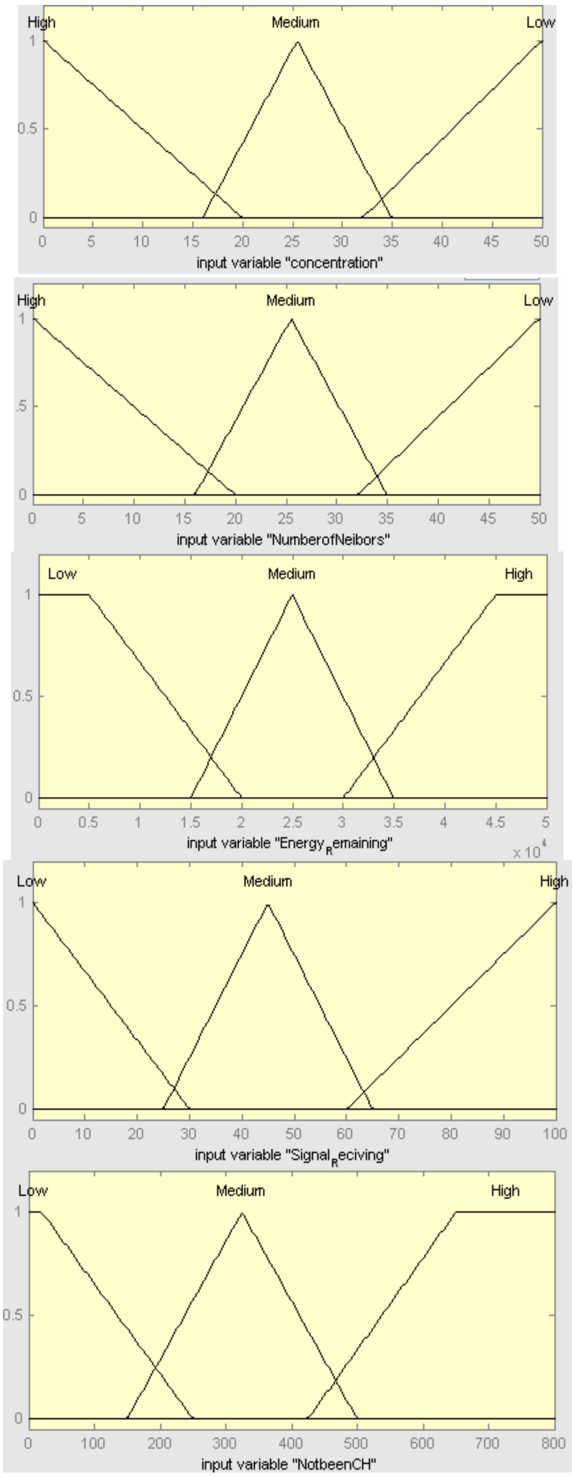


Figure 3. Input membership functions

In this stage (fuzzy inference) we use mamdani inference method to determine output from inputs. some rules that mamdani method uses them are listed in table I.

TABLE I. SOME OF THE EXISTENCE RULES

Received signals	**Absence rounds of CH**	**Centrality**	**Number of neighbors**	**Energy remaining**	**Output**
L	L	L	L	L	VL
H	H	H	H	H	VH
M	H	M	M	M	H
M	L	M	M	H	H
M	M	M	M	M	M
M	L	M	M	L	L
H	H	L	L	H	VH
L	H	L	L	H	H
L	H	L	L	L	L
M	L	H	H	L	L

Legend : L:Low , M: Medium , H : High , V : Very, CH : Cluster Head.

We need a membership function to convert the obtained output from fuzzy to crisp in the fuzzification stage. This function is shown in fig. 4.

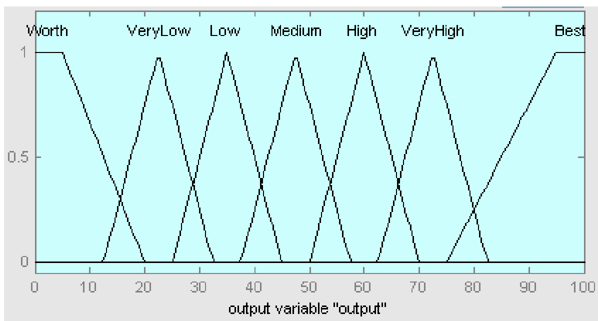


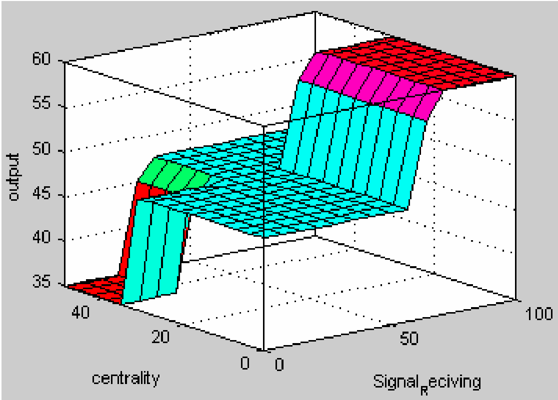
Figure 4. Output membership function

In this paper we use of Center of Area (COA) method to deffuzification output. Threshold (α) obtained from formula 2.

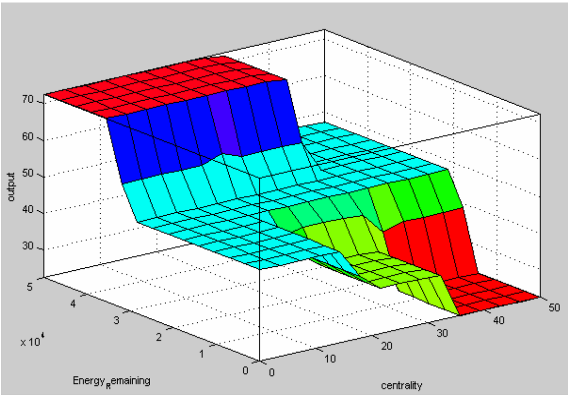
$$\alpha = \frac{\int_z \mu_A(x)\, z\, dz}{\int_z \mu_A(z)\, dz} \tag{2}$$

Where α is the non-fuzzy output for the fuzzy system (z) and $\mu_A(Z)$ is aggregated output membership function. Now we rewrite formula 1 as formula 3.

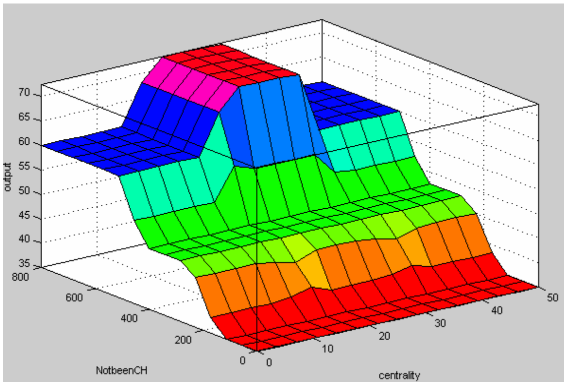
$$T(n) = \alpha \quad \text{if } n \in G$$
$$T(n) = 0 \quad \text{Otherwise} \tag{3}$$



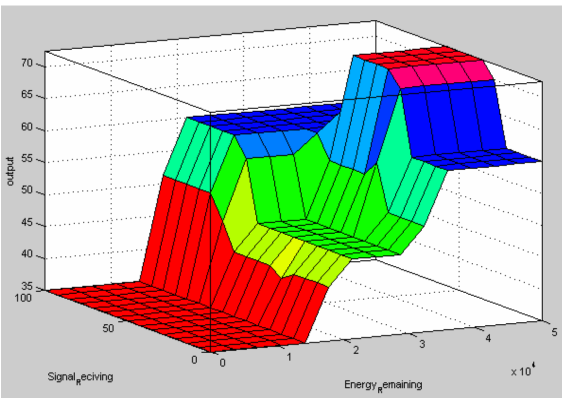
5.a) centrality and received signals



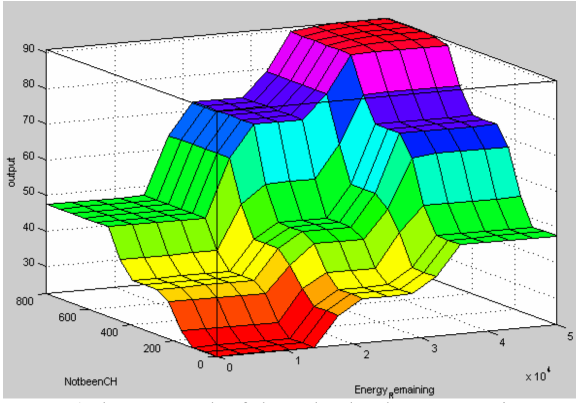
5.b) centrality and energy remaining



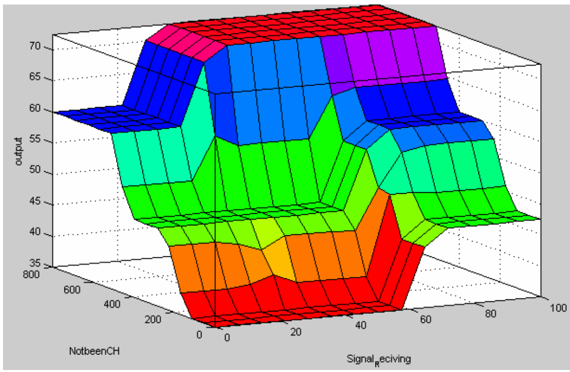
5.c) centrality and absence rounds of cluster head



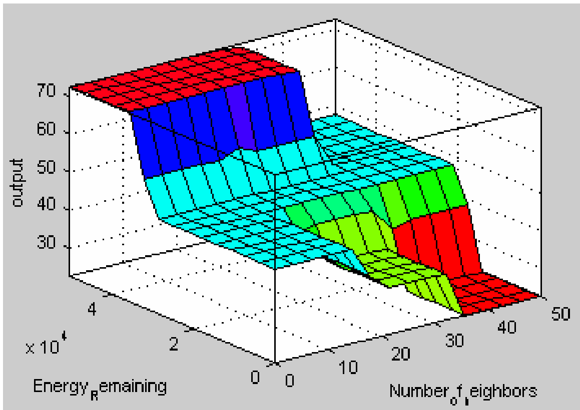
5.d) received signals and energy remaining



5.e) absence rounds of cluster head and energy reaming



5.f) absence rounds of cluster head and received signals



5.g) number of neighbors and energy remaining

Fig. 5. influence of inputs on output

Each node after calculates T(n), generates a random number between 1,0. If in a node T(n) is greater than the random number, This node becomes cluster head and make a cluster.

V. Simulation Results

We use of Matlab [11] for simulations. Fig. 6 shows influence of some fuzzy inputs on the output (α).

This figure shows that energy remaining and absence rounds of cluster head are more influential on the output.

To compare with LEACH and LEACH-FL, the networks that have an area of 100*100 with 20 nodes are selected. The coordinate of the BS is (50,200) and the energy parameters are shown in table II.

TABLE II
Energy parameters

Initiate energy	0.5J	Eelect	50nJ/bit
Єfs	10pJ/(bit*m2)	Єamp	0.0013pJ/(bit*m4)

Fig. 7 shows difference between proposed method and LEACH and LEACH-FL in energy consumption. consider that the proposed method consumes less energy than other two methods and thus the network lifetime increased. Fig. 8 shows alive nodes in these methods.

It is clear that our proposed method does work well in all cases.

VI. Conclusion

Our aim of doing this research is to achieve an optimal approach for clustering in WSN. This method has less computational complexity because uses of fuzzy logic. Since all operations for cluster formation are done locally a large amount of energy is saved and speed of cluster formation is increased. Moreover, this method is extremely robust because using appropriate input for the fuzzy system. We propose an efficient clustering approach by combination good features of LEACH approach and fuzzy logic. This method works better than other clustering approaches.

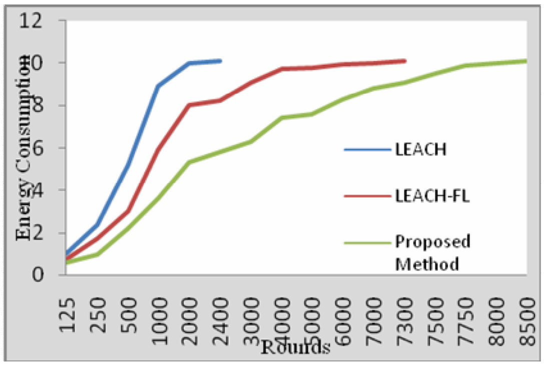


Fig. 6. Energy consumption

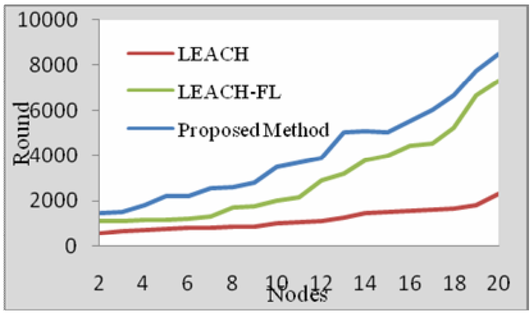


Fig. 7. Nodes

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