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# INCREASING THE LIFETIME OF HETEROGENEOUS SENSOR NETWORK BY USING GENETIC-FUZZY CLUSTERING

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**Abstract**—Wireless sensor network is composed of hundreds or thousands of sensor nodes which have computational, energy and memory limitation. Its duty is to receive information from its surrounding environment, analyze and process data and to send the received data to other nodes or base station. In these networks, sensor nodes are dependent on low power batteries to provide their energy. As energy is a challenging issue in these networks, clustering models are used to overcome this problem. In this paper, fuzzy logic and genetic algorithm are combined to increase the lifetime of the wireless sensor network. In other words, fuzzy logic is used to introduce the best nodes, those that in comparison to other nodes have more energy, density and centrality, to base station as cluster head candidate. Then, the number and place of cluster heads are determined in base station by using genetic algorithm. Also, the network acts heterogeneously and includes several nodes with different parameters.

***Keywords***-*genetic algorithm;clustering;wireless sensor network;fuzzy logic;lifetime;*

## I. INTRODUCTION

Wireless sensor networks are a new generation of recent networks with computational, energy and memory limitation [1]. The wireless sensor network includes hundreds or thousands of sensors that usually are scattered in an inaccessible environment. The main duty of these sensors is to collect information from surrounding environment and send it to base station [2].Each sensor node is composed of sensor, computational, memory and wireless communication unit with a limited board. Wireless sensor networks are used in army, hygiene, education, industry, agriculture and etc. [3]. In these networks, sensor nodes are dependent on low power batteries to provide their energy. Because these networks are used in dangerous and inaccessible environments, it is hard or even impossible to charge or change their energy source. Therefore, one of the main challenges of these wireless sensor networks is the sensors' low energy [4]. These networks efficiency depends on the lifetime of sensor nodes and network coverage. Therefore, it's important to optimize energy consumption and manage the consumption power of sensor nodes. Most of energy consumption in these networks is due to information transference inside the network .clustering is one of the common solutions to decrease the number of network's internal transference [5]. In clustering sensor nodes are divided into some clusters and in each cluster one node is chosen as cluster head to receive data from other nodes and send them to base station. Selecting a suitable cluster head decreases energy consumption to a great extent and as a result increases networks' lifetime [1, 2]. In recent years, due attention has been paid to powerful methods such as: fuzzy logic, genetic algorithm and neural networks [6, 7, 8,9].

In LEACH protocol [10], cluster heads are chosen first and then the members of each cluster head are determined. Cluster members send the received data to cluster head according to TDMA scheduler. Cluster head combines the received data and sends it to base station. As this algorithm just uses local information, the number of cluster heads in each round is not fixed and it may be less or more than the optimized amount in one round. Also, each node should produce and compute a random number and a threshold level in every round.

ECS algorithm has improved LEACH method by changing probability. In probability function, energy parameter has been considered to choose cluster heads. Also reduction in search space has increased clustering speed [11].

In [13], in order to choose cluster heads, a two level fuzzy method is used that includes local level and global level. In local level, node’s capability for being cluster head has been evaluated based on two parameters: energy and the number of neighbors. In global level three parameters have been considered: Centrality, closeness to base station and the distance between cluster heads.

This paper is organized in 4 sections. In section 2 the proposed algorithm to increase the lifetime of wireless sensor network is mentioned. Simulation and evaluation of the aforementioned algorithm are presented in section 3.section 4 is allocated to conclusion.

## II. THE PROPOSED ALGORITHM

As in this paper a new idea is mentioned to increase the lifetime of wireless sensor network and combination of various algorithms are used to achieve our purposes, therefore, the Existing network is examined through fuzzy logic and genetic algorithms from these aspects:

- The lifetime of network.
- The selection of cluster head in each round.
- The number of dead sensors after each round.

In this section, the hypotheses, the problem and the suggested algorithm are explained. The paper's hypotheses are:

- Sensors are fixed in their place.
- In any round, each sensor can just send or receive data.
- Sensing the environment and preparing the data of each sensor node in order to send it, is done independently.
- Each node sends its position and remaining energy to its cluster head in the form of control packets.
- Base station has enough knowledge about the position of network nodes.
- Each node is equipped to a GPS system and finds its place and geographical position.

Heinzelman's energy model [10] is used for sensor network. Consumed energy to send a message with *k* bits length in *d* distance is computed through the (1).

$$E_{TX}(k,d) = \begin{cases} k \times E_{elec} + k \times \varepsilon_{fs} \times d^2, if \ d \le d_0 \\ k \times E_{elec} + k \times \varepsilon_{mp} \times d^4, if \ d \ge d_0 \end{cases} \quad (1)$$

Where $E_{elec}$ the energy dissipated per bit to run the transmitter or the receiver circuit, $\varepsilon_{fs}$ and $\varepsilon_{mp}$ depend on the transmitter amplifier model we use, and d the distance between the sender and the receiver. By equating the two expressions at $d = d_0$, we have: $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$.

Each node's consumed energy to receive a *k* bit message is computed through the (2). $E_{TR} = k \times E_{elec}$ (2)

In the proposed method, the same as LEACH algorithm, the period of network's activity is divided into some rounds and each round includes two phases: setup phase and steady state phase.

### *A. Setup Phase*

In the first phase, cluster heads are selected and then the clusters ' members are determined. In this phase, each node calculates its chance parameter based there main characteristics through fuzzy logic: its energy, density and centrality in comparison with neighbors. Nodes with higher capability introduce themselves to base station as cluster head' candidate, so they prevent those nodes which are not capable of being cluster head from sending their information. The network uses nodes with different factor after being launched. Nodes that remaining energy in comparison with network's total energy is less than threshold level are recognized as dead nodes and can't participate in competition. In base station, cluster heads are determined among cluster head candidates using genetic algorithm. Also, the number of times in which a node is selected as cluster head is considered. Then, base station sends a message including cluster head's ID to each node. If a node's cluster head ID conforms to the node's ID, that node is a head a cluster. Base station creates a Time division multiple access table and this table is sent to cluster heads. TDMA table is used to time the data transfer of sensor nodes and also enables sensor nodes to turn off their radio antenna and save their energy until it's time for them.

### *B. Steady State Phase*

In the second phase, cluster members send the received data to cluster head according to TDMA table and after receiving data, cluster heads compress and send them to base station.

### *C. Fuzzy Logic Control*

In the proposed method, we have used the most commonly used fuzzy inference technique called Mamdani Method. Input parameters of fuzzy logic controller in the proposed method are:

- Node's energy: energy variable shows the remaining energy in proportion to the network's total energy.
- Node's density: density variable shows the number of a node's neighbors that their distance to the controlled sensor is less than *n*.
- Node's centrality: centrality variable shows how close a node is to a cluster.

In order to compute the number of neighbor's sensors in the beginning of network's activity, each sensor sends its ADV message to neighbor nodes in a definite radius; thus, each sensor calculates the number of its neighbors based on the energy of the received signal. ADV message is a message to introduce sensor in the network. In order to calculate the amount of centrality, each node computes its distance to those neighbors which exist in *n* radius and their sum shows the amount of centrality variable. Language variables for each of the inputs are: Energy = (low, med, high) , Density = (low, med, high) and Centrality = (close, adeq, far). Figure 1 shows fuzzy rule base which are used in this structure.

1.(density== Low) &( Energy== low) &( Centrality== close)=>(Output== Small)
2.(density== Low) &( Energy== low) &( Centrality== adeq)=>(Output== Small)
3.(density== Low) &( Energy== low) &( Centrality== far) =>(Output== Vsmall)
4.(density== Med) &( Energy== low) &( Centrality== close)=>(Output== Small)
5.(density== Med) &( Energy== low) &( Centrality== adeq)=>(Output== Small)
6.(density== Med) &( Energy== low) &( Centrality== far) =>(Output== Small)
7.(density== High) &( Energy== low) &( Centrality== close)=>(Output== Rsmall)
8.(density== High) &( Energy== low) &( Centrality== adeq)=>(Output== Small)
9.(density== High) &( Energy== low) &( Centrality== far) =>(Output== Vsmall)
10.(density==Low) &( Energy== med) &( Centrality== close)=>(Output== Rlarg)
11.(density==Low) &( Energy== med) &( Centrality== adeq)=>(Output== Med)
12.(density==Low) &( Energy== med) &( Centrality== far) =>(Output== Small)
13.(density==Med) &( Energy== med) &( Centrality== close)=>(Output== Large)
14.(density==Med) &( Energy== med) &( Centrality== adeq)=>(Output== Med)
15.(density==Med) &( Energy== med) &( Centrality== far) =>(Output== Rsmall)
16.(density==High) &( Energy== med) &( Centrality== close)=>(Output== Large)
17.(density==High) &( Energy== med) &( Centrality== adeq)=>(Output== Rlarge)
18.(density==High) &( Energy== med) &( Centrality== far) =>(Output== Rsmall)
19.(density==Low) &( Energy== high) &( Centrality== close)=>(Output== Rlarge)
20.(density==Low) &( Energy== high) &( Centrality== adeq)=>(Output== Med)
21.(density==Low) &( Energy== high) &( Centrality== far) =>(Output== Rsmall)
22.(density==Med) &( Energy== high) &( Centrality== close)=>(Output== Large)
23.(density==Med) &( Energy== high) &( Centrality== adeq)=>(Output== Rlarge)
24.(density==Med) &( Energy== high) &( Centrality== far) =>(Output== Med)
25.(density==High) &( Energy== high) &( Centrality== close)=>(Output== Vlarge)
26.(density==High) &( Energy== high) &( Centrality== adeq)=>(Output== Rlarge)
27.(density==High) &( Energy== high) &( Centrality== far) =>(Output== Med)

**Figure 1. Fuzzy Rule base**

The second parameter is the number of received messages.

### *D. Using genetic algorithm*

Determining the number and place of cluster heads has always been a challenge. The dynamic nature of issue, due to the frequent changes in cluster heads in each round of network's activity, makes the issue more complex and as result modeling is not possible through math classic methods. Common clustering algorithms in other studies have benefited from heuristic methods. On the other hand, genetic algorithm is so flexible in solving dynamic issues. In this paper, genetic algorithm is used to determine the place of cluster heads in a way that the minimal amount of energy is consumed. Fitness Criterion is based on the minimal consumed energy from network nodes in each generation. In base station, the number of nodes that have introduced themselves as cluster head candidates determines the chromosome's length in genetic optimizing method. Each of this chromosome's genes recognizes some of the sensor network nodes. Chromosome's structure is defined as: $chrom = \{g_i \mid i = 1,2,3,...,l\}$,where $l$ is the chromosome's length and $g_i$ is the *i-th* gene.

After crossover operator, mutation happens in a way that a mutation may be created in a bit of one or some chromosomes. Finally, after crossover and mutation, base station selects the chromosome which has the networks least energy difference in proportion to the previous round and introduces the available nodes to network as cluster head and other nodes join to the nearest cluster head. If we show the network's current energy in *k-th* round with $E^{k}_{Network}$, fitness function is computed through the (3) that should become minimum and in this equation, | | sign indicates absolute value.

$$fitness = \left| E^{k}_{Network} - E^{k-1}_{Network} \right| \quad (3)$$

## III. SIMULATION AND RESULT

As the most important part of each paper is allocated to its results, this section examines this paper's results. Ns2 simulator is used to simulate the proposed algorithm. 100 sensor nodes are used in the simulation. The parameter values used in the simulation are same as Table I.

TABLE I. The Values Of The Simulation Parameters

| parameters | Values |
|---|---|
| Network dimensions | 100*100 $m^2$ |
| $\varepsilon_{fs}$ | 10 pJ/bit/$m^2$ |
| $\varepsilon_{mp}$ | 0.0013 pJ/bit/$m^4$ |
| $d_0$ (distance threshold) | 87 m |
| $E_{DA}$ (Energy aggregation Data) | 5 nJ/bit/signal |
| Average of normal data packet size | 4000 bits |

As most of the presented methods are random ones, each of the methods are executed for five times and the average of achieved amounts in each simulation is used to examine the function of each method. In order to decrease the complexity and have a simpler comparison among the presented methods, one base station is used. In this section, the proposed algorithm is compared to the GFS algorithm [13] which works based on fuzzy logic and genetic algorithm from two aspects:

- The time of first sensor node's death.
- The time of whole network's death (the time in which sensor node's energy is finished completely).

In this paper three scenarios are used to compare the efficiency of the suggested algorithm. Finally, the proposed algorithm leads to the lightest lifetime in sensor's network.

- First scenario: In this scenario, the proposed algorithm is evaluated in the form of a heterogeneous network with three different nodes: An advanced node, a normal node and a node which is in a critical condition and has the lowest energy level.
- Second scenario: In this scenario, the proposed algorithm which is a heterogeneous network with clustering routing is considered in a fuzzy state in which each node determines its capability

for being a cluster head based on fuzzy logic.

- Third scenario: In this scenario, in addition to a network with heterogeneous nodes and fuzzy logic, genetic algorithm is used to select the cluster head in base station. In this section, the number of generations is 100, the crossover probability is 0.6 and mutation probability is 0.05.

As the suggested algorithm works based on clustering, the most efficient route which has the highest energy and the least distance to base station is chosen and network's stability increases too. Figure 2 shows the comparison of the proposed algorithm to the GFS algorithm in each of the three scenarios based on the time of first sensor node's death.

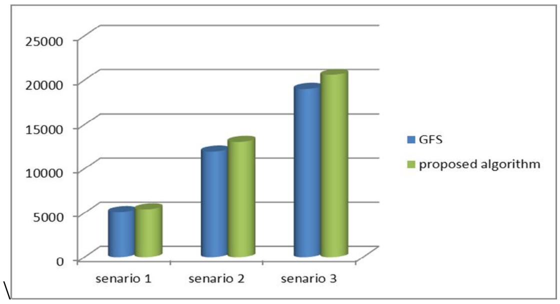


**Figure 2.** **The death time of the first node.**

Figure 3 shows the time in which all nodes' energy is finished. As the proposed algorithm uses clustering, fuzzy logic and genetic algorithm, sensor nodes use a lot of time to lose their energy.

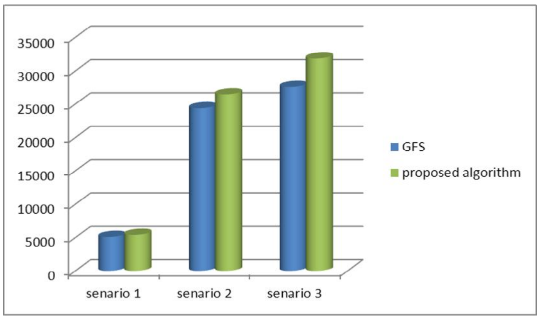


**Figure 3.** **The death time of total network.**

In this paper, network's lifetime was compared to LEACH and DEEC [14] clustering algorithms and the results show that by using fuzzy logic and genetic algorithm, the proposed algorithm works better than LEACH and DEEC. Network's lifetime parameter shows the time in which the first sensor node consumes its energy and dies. When the sensor node spends more time to consume its total energy, the network's stability is more. Figure 4 shows network's lifetime of proposed algorithm with comparison other algorithm.

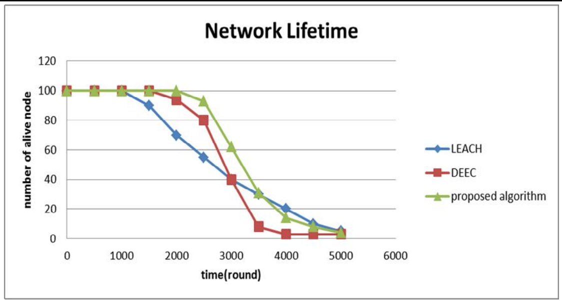


**Figure 4.** **comparison of network lifetime**

Figure 5 shows the number of received messages in base.

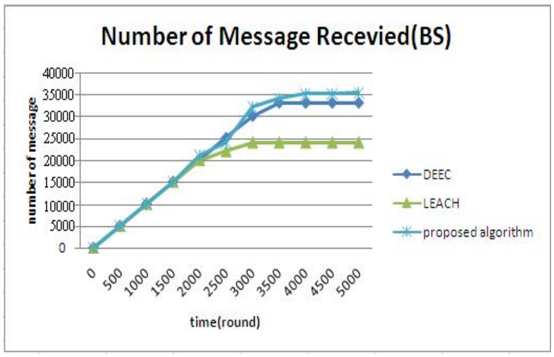


**Figure 5.** **Number of received messages in base station**

## IV. CONCLUSION

Optimum energy consumption in wireless sensor networks is important in such a way that optimum energy consumption will lead to an increase in the network lifetime. In this paper, a new method which is based on fuzzy logic and genetic algorithm is represented to select a cluster head in wireless sensor networks. Therefore, it is quicker and also more accurate to detect the node with higher energy and to select the cluster head. Moreover, this network has used nodes with heterogeneous characteristics. Some of the advantageous of heterogeneous nodes are: the long lifetime of networks, increase in network's reliability and decrease in data transference delay. In simulation, the proposed algorithm is compared to LEACH, EEC and GFS algorithms.

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