A New Clustering Algorithm Using Fuzzy Logic In Wireless Sensor Networks

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Abstract— **The network lifetime is one of the important factors in wireless sensor networks and is dependent on the network energy. Energy source in the network is very limited. In order to increase the network lifetime, energy saving should be considered. Clustering method is the one of the ways to consume energy efficiently that causes uniform load distribution and balanced energy consumption. In this essay, a new method for optimal selecting cluster head and clustering is presented using fuzzy logic. In the proposed method, a radius can be assigned for sensor with the help of fuzzy rules and fuzzy variables, energy and distance. Then cluster head sensors are elected with the help of fuzzy rules and energy and number of neighboring sensors as two fuzzy variables. Thus, the best sensors are selected as a Cluster head. Furthermore, with the help of obtained radius, cluster size is controlled with regard to distance from the base station. It means that clusters close to the base station are larger than far clusters. Therefore, in the proposed protocol the network energy consumption, which is uniformly distributed in the network, is reduced. MATLAB simulation results indicate that the proposed protocol managed to increase network lifetime more than LEACH and EECS protocols.**

Keywords- Cluster head, clustering, fuzzy logic, wireless sensor networks, network lifetime, sensor (node)

I. INTRODUCTION (HEADING 1)

Wireless sensor networks consist of many small, inexpensive sensors. Sensors are capable of processing, energy and have a limited memory. In wireless sensor networks, they collect data related to the environment events and send them to the base station [1]. Nowadays, wireless sensor networks have many usages in human life. Among these applications, monitoring the environment of humans and animals life, fire detection, flood, medical applications and military issues can be mentioned [2].

One of the most important factors in designing wireless sensor networks is energy. It is not possible to recharge or replace the sensors energy sources since the energy source in sensors is limited (because of the numerous number of sensors) and lack of access to them in different geographic environments in the network, [3] [4].

Therefore, energy is very important in saving wireless sensor networks and many researches have been presented on the field of optimizing energy consumption and increasing network lifetime. Among the protocols presented, hierarchical protocols based on clustering are efficient in energy consumption.
In these protocols, the network is divided into parts called clusters. In each cluster, a sensor is selected as a cluster head. Other cluster sensors collect data from the environment and send them to cluster head. After data collection, cluster head aggregates them in order to delete repetitive data and eventually sends them to the base station. In these protocols, only cluster heads communicate with the base station and other sensors are connected to cluster heads.

Therefore, in these protocols, selecting a sensor as cluster head and aggregating data will significantly result in saving energy. Reducing energy consumption can increase the network lifetime because of direct connection in wireless sensor networks between reducing energy consumption and increasing the lifetime of the network. In this essay, a new efficient protocol in energy consumption is presented with the help of fuzzy logic and considering distance and energy as two variables to determine the sensors radial range and considering energy and number of the neighboring sensors as two variables in cluster head selecting process.

As we follow, in section 2 past works are discussed, in section 3 the proposed protocol is presented and in section 4 simulation is performed.

II. REVIEWING PAST WORKS

There have been many researches to optimize energy consumption in wireless sensor networks and a lot of clustering algorithms have been discussed. LEACH algorithm [1] [7] is one of the first cluster routing methods presented for sensor networks .In LEACH protocol, time is divided into the parts called the round and each round is divided into two phases. The first phase is called set-up phase in which clusters are formed and the second phase, which is related to normal network function, is called the steady-state phase .In the first phase, using a probability function, head clusters are selected. Each sensor selects a random number between zero and one. If this number is smaller than a specified threshold (T), the sensor is

selected as the cluster head during the round. This probability function is designed so that each sensor is selected as cluster head only once within a certain number of rounds, and thus energy consumption is spread over the entire network. After cluster heads were selected in the set-up phase, each cluster head announces the selecting news to the other sensors and other sensors select the nearest cluster head as their cluster head, then they inform the related cluster head. In the second phase, each sensor sends data to its cluster head and cluster head combines the received data and sends it to the base station.

LEACH protocol also has disadvantages. For example, the cluster head may be placed close to each other. In addition, remaining energy of the sensor for selecting cluster head is not considered; therefore, a sensor containing very little energy may also be selected as cluster head. Similarly, cluster head may be placed in one low-density position or be placed on the edge of the network.

LEACH-C algorithm [1], is the way in which the cluster heads are selected based on sensors position data and the amount of remaining energy. In the set-up phase, each sensor sends information about its status and remaining energy to the base station. Then the base station chooses the cluster heads based on this information. One of the advantages of this method is that by placing the head clusters in the center of cluster, the energy consumption will evenly be distributed between the sensors.

In algorithm [8], a cluster head selecting method is presented using fuzzy logic. In this protocol, cluster heads are selected with the help of two variables, energy and local distance, within a constant radius. Local distance is the total of the distances of neighboring sensors within the radius.

In [9], a fuzzy algorithm for selection of cluster heads has been suggested. In this algorithm, cluster heads are elected by the base station. It means at first the sensors send data to the base station in the network and the base station selects cluster head with the help of three fuzzy variables: energy, concentration and centrality.

In EECS-M algorithm [10], a clustering method based on energy level is presented. In this algorithm for each level of networks energy, a competitive radius is taken. Sensors at every level within their radius compete to be Cluster Head. Sensors within their radius are selected as cluster head based on remaining energy. In this protocol, clusters size are different from each other in terms of area in which the sensors are placed. It means that clusters close to the base station are larger than far clusters.

In EECS algorithm [11], the author considers a constant radius for all sensors. In addition, he/she uses a competitive algorithm for the phase in which cluster heads are selected. The candidate sensors in the constant competitive radius examine that if there is a sensor with more energy, they exit the competition and broadcast the exit message. A sensor, which has maximum energy in this radius, elects itself as a cluster head and broadcast the advertisement message. In this protocol, Cluster heads are uniformly distributed in the Network. Therefore, the size of the clusters is constant due to the constant competitive radius.

III. THE PROPOSED ALGORITHM

The proposed algorithm is among those clustering algorithm. In this protocol, it has been attempted to reduce energy consumption and increase network lifetime using fuzzy rules .Cluster head energy consumption is different with regard to the distance from the base station. Cluster heads, which are close to the base station, consume the less energy for sending aggregated data than cluster heads far from the base station. For this reason, the far cluster heads lose their energy faster in the protocols that elect cluster heads without regard to the remaining energy and distance. In addition, the size of the clusters is effective in the cluster heads energy consumption. It means that cluster heads will consume more energy in the large clusters. Therefore, in this paper, using fuzzy rules for sensors, based on the amount of remaining energy and the sensor distance from the base station, a radius is considered. Then for selecting cluster heads for sensors, a chance is obtained in terms of fuzzy rules and based on remaining energy of the sensor and the number of neighbors within the related radius. Then the sensor, which has a maximum chance within its radius, is selected as cluster head and broadcasts the advertisement message to the network. Thus, the proposed protocol with selecting high-energy sensors as cluster head and limiting the size of clusters with regard to the distance from the base station cause energy consumption to reduce and ultimately lead to increasing network lifetime.

A. Network Model

Network is intended with the following specifications:

- Sensors are homogeneous and are distributed uniformly in the square area.
- Base station and sensors are fixed (static and unchanging).
- The base station is located outside square area.
- All sensors have the same initial energy.
- Sensors are aware of their position.

B. radio model

Radio model is discussed in [12] and used as the connecting model among the sensors. Equation (1) shows the amount of energy to transfer an L-bit packet to the distance d. E_{elec}, shows the amount of consumption energy of the transmitter and receiver circuits. $\boldsymbol{\varepsilon_{fs}}$ and $\boldsymbol{\varepsilon_{mp}}$, shows the amount of waste energy to boost the RF at a distance d_0 which is obtained by using equation (2):

$$E_{TX} = \begin{cases} L \times E_{elec} + L \times \varepsilon_{fs} \times d^2 & d \langle d_0 \\ L \times E_{elec} + L \times \varepsilon_{mp} \times d^4 & d \geq d_0 \end{cases} \quad (1)$$

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (2)$$

Consumed energy to receive an L-bit packet is also calculated by using equation (3):

$$E_{RX} = L \times E_{elec} \quad (3)$$

Consumed energy in cluster heads is also calculated during a round by using equation (4):

$$E_{CH} = (\frac{n}{k} - 1) L \cdot E_{elec} + \frac{n}{k} L \cdot E_{DA} + L \cdot E_{elec} + L \cdot \varepsilon_{fs} \cdot d^4_{to-BS} \quad (4)$$

K shows the number of clusters and E_{DA} determines data combination cost. $d^4_{\text{to-bs}}$ is the average distance between cluster head and the base station. The consumed energy in conventional sensors is also calculated by using equation (5):

$$E_{CM} = L \cdot E_{elec} + L \cdot \varepsilon_{fs} \cdot d^2_{to-CH} \quad (5)$$

$d^2_{\text{to-bs}}$ is the average distance between the cluster member sensors and cluster head.

C. *The working process of the proposed algorithm*

This essay assumes that the sensors calculate their distance from the base station by receiving the message from the base station. Each sensor is aware of its position and its remaining energy. In the proposed protocol like LEACH protocol, time is divided into parts that are called the round. In each round, there are both set-up phase and steady-state phase. In set-up phase, radius and a chance are calculated for the sensors. Then cluster heads are selected and clustering is performed. In stable phase, data is collected, aggregated and sent to the base station by cluster heads.

1) Determining the radius for sensors with the help of fuzzy function

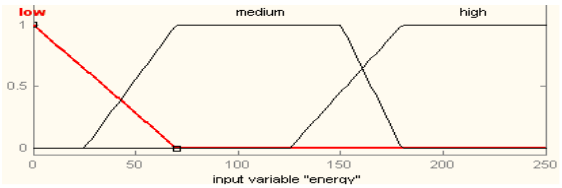
As previously discussed, each sensor is aware of its remaining energy and distance from the base station. In this protocol, for reducing energy consumption a radius is considered for each sensor in terms of the remaining energy and distance from the base station. In the case of electing as a cluster head, this radius makes sensor have a clustering limited to its radius in order to prevent rapid energy discharge; because cluster heads, which are far from the base station, have more energy consumption. For determining the radius in fuzzy function, fuzzy rules use two fuzzy variables, which are defined as follows:

- Energy: The amount of remaining energy of sensor.
- Distance: the distance of a sensor from the base station.

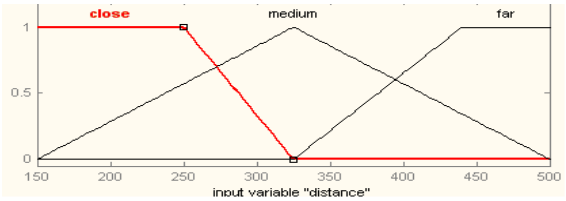
Fuzzy function acquires the radius in terms of these two variables with the help of fuzzy rules. Thus, if energy is high and distance is close, radius will be become larger. Energy consumption for data transmission to the base station is low in those sensors, so large radius is considered in order to have a bigger cluster. On the other hand, if energy is low and the distance is far, radius is considered too small. The used fuzzy rules to calculate the radius are shown in table 1 and fuzzy sets are shown in figure 1.

TABLE I. FUZZY IF-THEN RULES FOR RADIUS

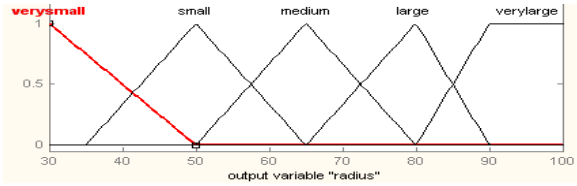
Energy	Distance	Radius
1-low	Far	Very small
2-low	Medium	Very small
3-low	Close	Small
4-medium	Far	Small
5-medium	Medium	Medium
6-medium	Close	Large
7-high	Far	Medium
8-high	Medium	Large
9-high	Close	Very large



1-a) energy



1-b) distance



1-c) radius

Figure 1. fuzzy sets for radius

2) Calculating the chance for sensors with the help of fuzzy rules

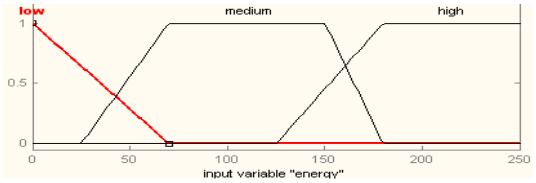
After determining the radius for the sensors, the amount of chance to be cluster heads is calculated. To calculate the chance in terms of fuzzy rules, the following two variables are used:

- Energy: the remaining energy of the sensor.
- Neighbor: the number of neighbors in the sensor radius.

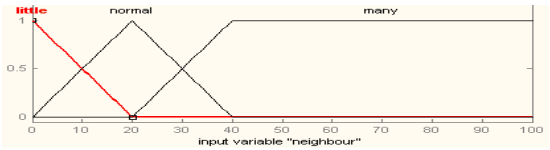
In this protocol, sensors, which contain high-energy and a great number of neighbors, have more chance to become cluster head, because these sensors are able to manage large clusters. Considering the number of neighbors will result in minimizing the number of cluster heads. Energy consumption is more in cluster heads; therefore, it reduces energy consumption in the network. The used fuzzy rules for chance calculating are shown in Table 2 and fuzzy sets in Figure 2.

TABLE II. FUZZY IF-THEN RULES FOR CHANCE

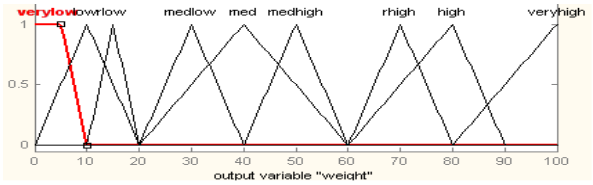
Energy	Neighbor	Chance
1-low 2-low 3-low 4-medium 5-medium 6-medium 7-high 8-high 9-high	Little Normal Many Little Normal Many Little Normal Many	Very low Low Rather low Med low Med Med high Rather high High Very high



2-a) energy



2-b) Neighboring sensors



2-c) chance

Figure 2. Fuzzy sets for the chance

3) Eelecting cluster head and clustering

After determining the radius and calculating the chance using fuzzy rules, cluster heads should be elected. A sensor with maximum chance is elected as a cluster head. Each sensor searches the area within its radius for maximum chance. If there is no sensor with more chance, the sensor elects itself as the cluster head and broadcasts the advertisement message to the network. Other sensors, after receiving the message, inspect that if they place within several cluster heads limits, they choose the nearest cluster head as their cluster head and send the Join message to it.

IV. SIMULATION

In this paper, the provided protocol and LEACH and EECS protocols have been simulated using MATLAB. For this purpose, a 300m × 300m network is considered. Sensors are uniformly distributed in the network. The position of the base station is in the 150m × 450m in the network. Initial energy is 0.5 J for each sensor. The test values for Eelec, ε fs, ε mp and E DA is respectively considered 50 nJ/bit, 10 pJ/bit/m2, 0.0013 pJ/bit/m4 and 5 nJ / bit / signal. In Figure 3, the average of live sensors (node) in the network is shown with scenarios (different cases), 100,200,300,400, and 500 sensors. As we can see, the average of live sensors in proposed algorithm is more than the LEACH and EECS algorithms because in the proposed algorithm, cluster heads and the size of clusters are selected in terms of fuzzy rules; as a result, load is optimally distributed.

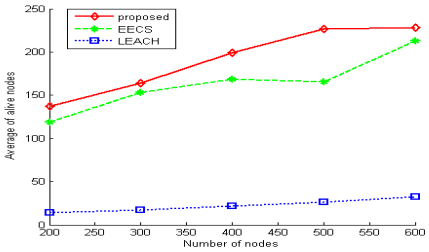


Figure 3. the average of live sensors in the network with scenarios, 100,200,300,400 and 500 sensors

In Figure 4, the average energy of total network is shown with scenarios, 100,200,300,400 and 500 sensors. As we can see, the average of the network energy in the proposed algorithm is more than LEACH and EECS algorithms because in the proposed algorithm the sensors radius is determined in terms of fuzzy rules; therefore, the far cluster heads lose their energy slower. In addition, the best sensors are selected as cluster head.

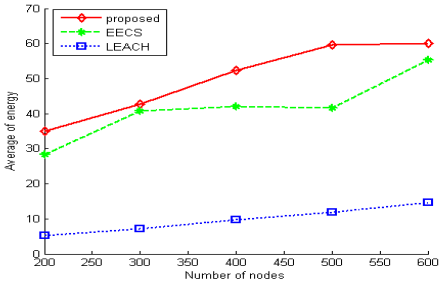


Figure 4. Average energy network with scenarios, 100,200,300,400 and 500 sensors

In figure 5, the average number of sent packets to the base station in network is shown respectively in the proposed algorithm and EECS and LEACH algorithms.

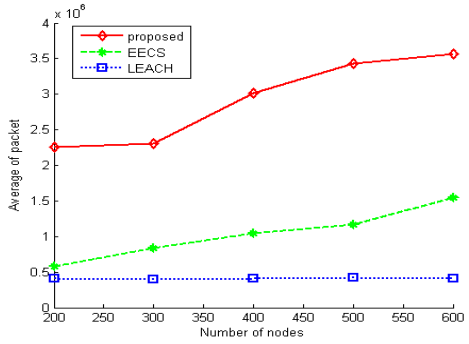


Figure 5. Average number of sent packets to BS with scenarios, 100,200,300,400 and 500 sensors

In figure 6, number of cluster heads in the network with 100,200,300,400 and 500 sensors is shown respectively in the proposed algorithm and EECS and LEACH algorithms. As we can see, the number of the cluster heads is higher than the proposed algorithm.

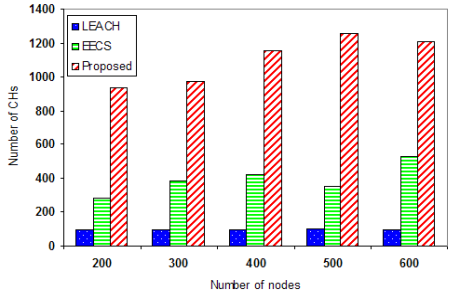


Figure 6. number of cluster heads of in the network with scenarios, 100,200,300,400 and 500 sensors

In figure 5, the first dead sensor based on number of round in the network with 100,200,300,400 and 500 sensors is shown respectively in the proposed algorithm and EECS and LEACH algorithms. As we can see, in the proposed algorithm, the network loses its first sensor slower than the EECS and LEACH algorithms.

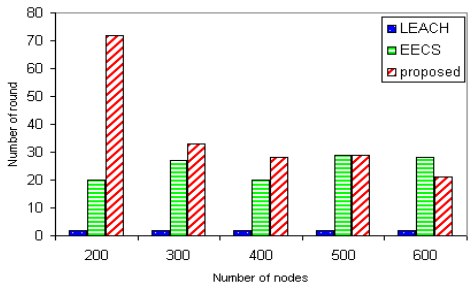


Figure 7. The first dead sensor based on number of round

V. CONCLUSION

In this paper, a protocol has been presented for the selection of cluster head using fuzzy logic. In this protocol, using fuzzy logic, a radius is considered for each sensor. Then with the help of fuzzy rules, Cluster Heads are chosen based on the variables such as remaining energy and the number of neighboring sensors within the related radius. Since energy consumption is high in cluster heads, selecting them based on energy will result in having enough energy to perform and avoiding rapid discharge energy.

Determining the radius in terms of fuzzy rules for the sensors also helps to obtain the number of neighbors within the radius. In addition, the size of the clustering is limited to the radius. Therefore, large clusters can be formed nearer than the small clusters to the base station. Thus, the proposed protocol reduces the energy consumption and increases the network lifetime. Simulation results confirm that the proposed protocol performs better than the LEACH and EECS protocols in terms of energy consumption and lifetime.

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