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CFMTL: Clustering Wireless Sensor Network Using Fuzzy Logic and Mobile Sink In Three-Level

Ali Abdi Seyedkolaei[1] and Ali Zakerolhosseini[2]

[1] Department of Computer, Shahid Beheshti University, Tehran, Iran
Aabdi64@gmail.com

[2] Department of Computer, Shahid Beheshti University, Tehran, Iran
Ali.zaker@sbu.ac.ir

Abstract

Lifetime enhancement has always been of crucial importance for energy constrained sensor network due to resource limitations of sensor nodes. The protocol play important roll, which can minimize the delay while offering high energy efficiency and long span of network lifetime. This paper concentrate on energy optimization by introducing a novel and an adaptive clustering algorithm that is fuzzy logic and mobile sink based. In this paper, a three- level fuzzy logic is utilized to evaluate the Priority of sensors to become a cluster head. In the first level, the qualified nodes are selected based on their residual-energy and density of them. Then, in the second level, nodes overall cooperation is considered in the whole network with three fuzzy parameters. These parameters are centrality, proximity to base station and distance be- tween cluster-heads. In the third level, the sink is move based on two parameters energy of cluster heads and distance of cluster heads to sink. This paper compares the result of this CFMTL approach to LEACH, Fuzzy, GA and FGA algorithms.

Keywords: *Wireless Sensors Network, Network lifetime, Energy Efficient, Fuzzy logic, Mobile Sink.*

1. Introduction

Advances in Micro Electro-Mechanical System (MEMS) technologies, embedded computing technologies and wireless communication technologies have enabled the development of relatively inexpensive and low-power-consumption micro sensors with the capability of sensing, computing and communicating. Composed of a large number of these sensor nodes, a Wireless Sensor Network (WSN) can be used for detecting, collecting and analyzing the information of complex environments in real time. WSNs can be used in many applications such as military, biomedical, and environmental applications. WSN routing technology is one of the most important technologies. According to the network architecture, WSN routing technologies can be divided into planar and hierarchical, and hierarchical network is also referred to cluster based. Many experiments have provided evidence that cluster based routing protocols work better in network topology management, energy minimization, data aggregation and so on than planar ones [1].In large scale networks, nodes are usually partitioned into a number of small groups, called clusters, for aggregating data through efficient network organization. In cluster based networks, cluster head nodes collect data packets from cluster members and transmit data to base station (BS) in either single hop or multi-hop mode by means of wireless communication.

Utilizing intelligent techniques improves the efficiency of wireless sensor network. In applications that require real time decision making, fuzzy logic is a powerful tool that can make decision even if there is insufficient data; while sufficient data (which is rare in real applications) is needed for making a decision in classic control. Recently, in some papers like [2] and [3], fuzzy logic is used for routing and improving network lifetime. We also used fuzzy logic as a mean to select cluster heads. In addition, due to the proved efficiency of clustering techniques in energy consumption, we utilized clustering in our proposed routing algorithm.

In this paper, we used a fuzzy logic in three-level to evaluate the Priority of sensors to become a cluster head and also transmission sink to suitable place to reduce energy consumption. In first level the qualified nodes are selected based on their residual-energy and density of them. Then, in the second level we seek for the best node cooperation regarding to the average energy consumption metric. In third level the sink is move based on two parameters energy of cluster heads and distance of cluster heads to sink.
In the remainder of this paper, Section 2 discusses some related works and previous studies. Section 3 describes the system and energy model and Section 4 discusses proposed algorithm. Section 5 provides simulation results and discusses the efficiency of proposed algorithm. Finally, Section 6 gives concluding remarks.

2. Related Work

In this section, we review related work in clustering algorithms. A main issue in the design of wireless sensor networks is the power dissipation scheme, hence the wireless node has a limited energy tag battery and has no backup power source until node death, thus, researches consider the design of low-power signal processing architectures, low power sensing interfaces, energy efficient wireless media access control and routing protocols, which revolves around energy balancing and management process.

LEACH [4] is one of the first hierarchical routing approaches for sensors networks, which attempts to improve energy and routing efficiency of such networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed.

In HEED protocol, residual energy of each sensor node is the primary parameter for probabilistic election of cluster-heads [5]. In case of a tie in cluster-head election, node degree or average distance to neighbors parameters are used to determine the cluster-head. Experimentations that are employed for evaluating HEED protocol show that clustering and data aggregation at least double the lifetime of the WSN.

In [6] authors have presented Intelligent Fuzzy-based cluster head selection system for WSNs and the performance has been analyzed. Selection of cluster head is difficult in different situations having different characteristics. Based on fuzzy theory and number of neighbor nodes, an energy efficient algorithm known as F3N has been developed by researchers. They have presented F3N algorithm for cluster head election using fuzzy theory.

In [2], Gupta used fuzzy logic to find cluster heads. In this algorithm three fuzzy variables is used for cluster head selection. Nodes energy, nodes concentration and nodes centrality are these parameters. In this approach, the base station primarily collects the necessary information from all nodes and then selects a node as a cluster head according to the fuzzy rules. In this approach there is only one selected CH for each round, whereas more CHs are needed for balancing energy consumption and improving network lifetime.

In [3], Kim offers CHEF in which, the same as [2], the CHs are selected based on a fuzzy logic. The difference is that in this approach more than one cluster head is selected locally in each round. The fuzzy set includes nodes energy and their local distances. CHEF [3] also generates a random number for each sensor and if it is less than a predefined threshold, Popt, then the nodes chance is determined. Thus, there may be some qualified nodes that lose their chance on a random manner.

In this paper, we used fuzzy logic in three-level to determine CHs in each round and also transmission sink to suitable place for prolonging network lifetime to an acceptable limit.

3. System and Energy Model

The mentioned network has following characteristics:

1. Nodes are randomly spread in the environment and nodes have been assumed homogeneous.
2. Initially, Base Station is located in the center of the environment.
3. Nodes are able to adjust their sending power according to their distance to the intended receiver.
4. All nodes have equal energy and ability.
5. Location and ID for all nodes is known for base station.
6. Sink is mobile and is moving on a square path.

Energy consumption model used in this article, is the same as energy consumption model in the LEACH [4] article. Each node to send l bit data to d distance of itself consumes as much as E_s energy, which is obtained from Eq. (1):

$$E_s = \begin{cases} IE_{elect} + IE_{fs} d^2 & d < d_{co} \\ IE_{elect} + IE_{fs} d^4 & d \geq d_{co} \end{cases} \quad (1)$$

Also the amount of energy that is used in the receiver for receiving l bit node is obtained from Eq. (2):

$$E_r = IE_{elect} \quad (2)$$

The assumption is that in each period, a cluster head receives only a packet from each node of its cluster. After receiving all packets, cluster head reports their useful information in the form of a single packet in a multi-hop manner to base station.

4. Proposed Algorithm

In this section, our proposed algorithm are presented to increase the network lifetime and energy consumption. Our method is composed of three levels that in the first level based on two parameters of the residual-energy and density is denoted cluster heads candidate each region. Density is the number of nodes adjacent to a node that will be useful range. Selecting region is that each node radius of R, all nodes within the radius is considered as the neighborhood and constitutes a region. In this level selection cluster

heads will be determined as Distributed. The cluster heads which are selected, are not final and only for best selection overall are transmitted to next level. The membership functions of these parameters are depicted in Fig. 1, 2 and 3. The fuzzy if-then rules in the first level are also shown in Table 1.

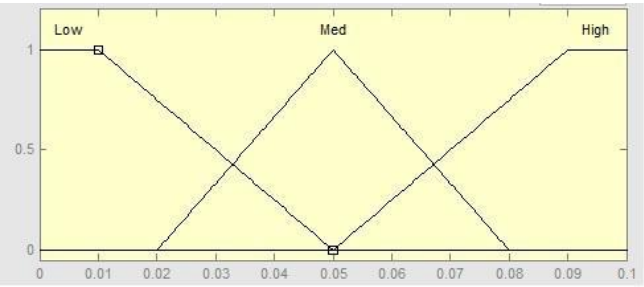

Fig. 1 Membership functions of residual-energy.

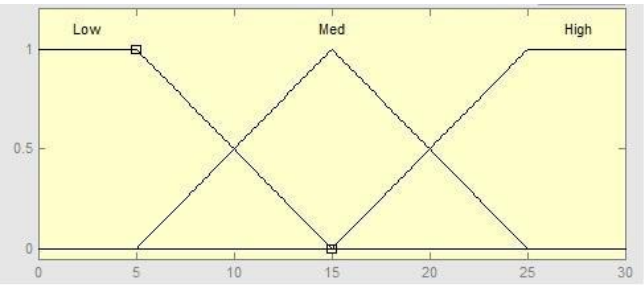

Fig. 2 Membership functions of density.

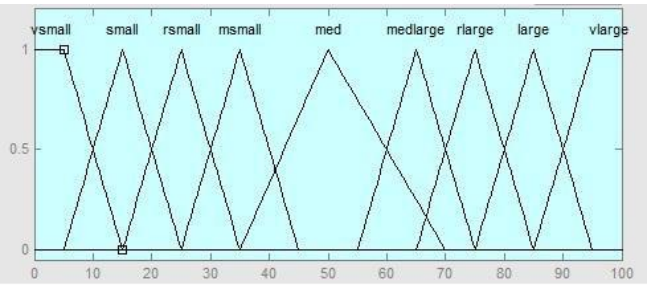

Fig. 3 Membership functions of priority in first level.

Table 1: Fuzzy rule base in first level

Residual-Energy	Density	Priority
Low	Low	Very Small
Low	Medium	Small
Low	High	Rather Small
Medium	Low	Medium Small
Medium	Medium	Medium
Medium	High	Medium Large
High	Low	Rather Large
High	Medium	Large
High	High	Very Large

In second level, cluster heads selection will be based on three parameters, centrality, proximity to base station and distribution between cluster heads that is their selection as focus. Centrality parameter defines that cluster head to what ex- tent is in the center of a cluster. Whatever of this amount be less than, expresses is the fact that normal nodes are located at a distance less than cluster head and this causes reduce the energy consumption of normal nodes during data transfer to its cluster head. The second parameter (proximity to base station) causes that sending data to base station reduced if it is close to cluster head. and the third parameter means distribution between cluster heads, in case of high its value, reduces energy consumption because whatever is much more, suggest that distance between cluster heads increased and better distribution have in whole network. If this value be lower, Causes aggregation cluster heads in area high and reduced distances to other areas and if normal nodes want send data, they consume much energy. In this case, the network lifetime reduces before the right time and the first dead node appears. The membership functions and the fuzzy rules of these parameters are depicted in Figures 4 to 7 and Table 2 respectively.

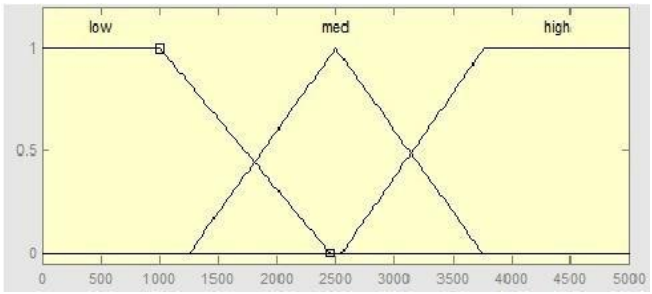

Fig. 4 Membership functions of centrality.

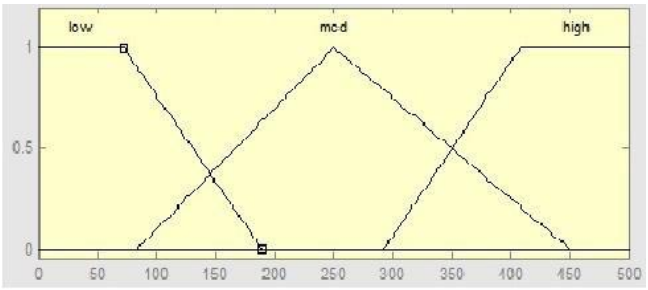

Fig. 5 Membership functions of proximity to base station.

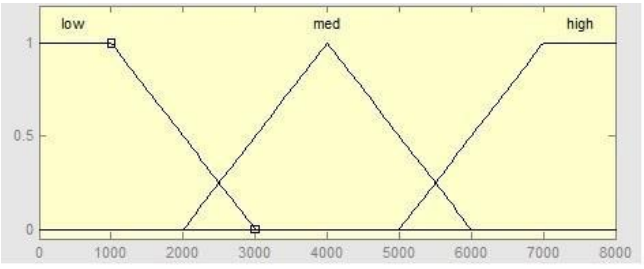

Fig. 6 Membership functions of distance between CHs.

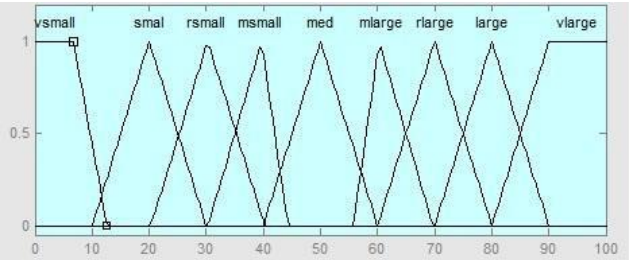

Fig. 7 Membership functions of priority in second level.

Table 2: Fuzzy rule base in second level

Centrality	Proximity to BS	Distance between CHs	Priority
Low	Low	Low	Large
Low	Low	Medium	Very Large
Low	Low	High	Very Large
Low	Medium	Low	Rather Large
Low	Medium	Medium	Large
Low	Medium	High	Large
Low	High	Low	Medium Large
Low	High	Medium	Rather Large
Low	High	High	Rather Large
Medium	Low	Low	Medium
Medium	Low	Medium	Medium Large
Medium	Low	High	Medium Large
Medium	Medium	Low	Medium Small
Medium	Medium	Medium	Medium
Medium	Medium	High	Medium
Medium	High	Low	Rather Small
Medium	High	Medium	Medium Small
Medium	High	High	Medium Small
High	Low	Low	Small
High	Low	Medium	Rather Small
High	Low	High	Rather Small
High	Medium	Low	Very Small
High	Medium	Medium	Small
High	Medium	High	Small
High	High	Low	Very Small
High	High	Medium	Very Small
High	High	High	Small

In the third level, we prioritize the cluster head based on two parameters, energy and distance to the sink through fuzzy logic. We consider cluster heads with low energy and long distance as the cluster head high priority and move the sink on the considered square path to be much close to a cluster head which is placed with high priority. We perform this operation in each round between the cluster heads. This operation causes the reduction of energy consumption and the increase of network lifetime. The membership functions and the fuzzy rules of these parameters are depicted in Figures 8 to 10 and Table 3 respectively.

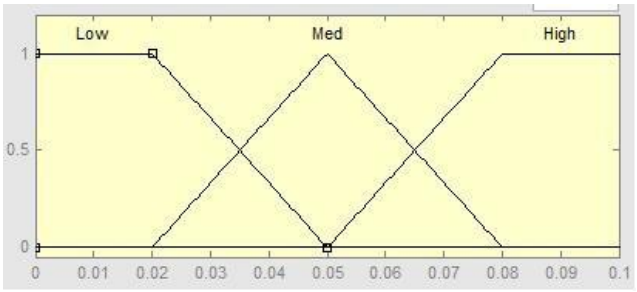

Fig. 8 Membership functions of energy.

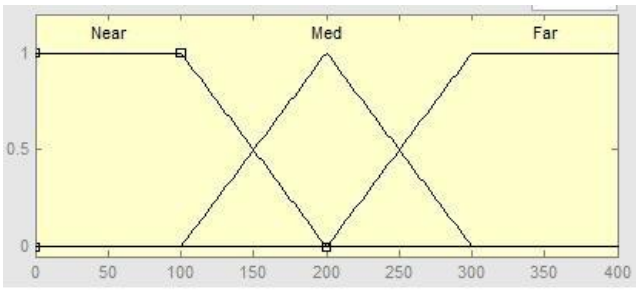

Fig. 9 Membership functions of distance.

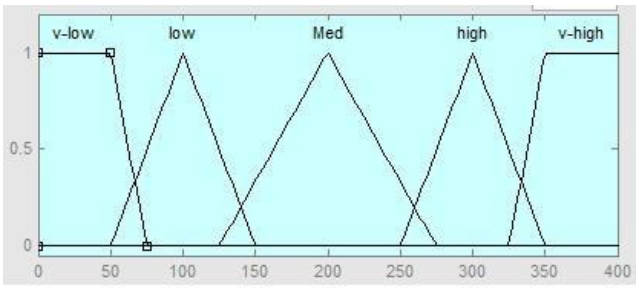

Fig. 10 Membership functions of priority in third level.

Table 3: Fuzzy rule base in third level

Energy	Distance	Priority
Low	Near	Very Small
Low	Med	Small
Low	Far	Rather Small
Medium	Near	Medium Small
Medium	Med	Medium
Medium	Far	Medium Large
High	Near	Rather Large
High	Med	Large
High	Far	Very Large

In this algorithm single-hop inter cluster and multi-hop intra cluster communications are used there on of using multi-hop communication is due to the Cluster heads that has further communication with the base station after collecting data from its cluster nodes which will send it to the nearest cluster head until will consume less energy to send their data directly to the base station and data with multi-hop intra cluster communication in each round are

sent to the base station. The way to choose a nearest cluster head which each cluster head of radius *R*, selects the head clusters according to proximity.
The important point is that in this algorithm in case a node proximity the base station to its cluster head can send their data directly to the base station which reduces the energy consumption in the network and this makes the method priority to the other methods.
Clustering operation is performed in each period, but it does not have to be changed in each step of the previous cluster head node because some Parameters which were considered for the fuzzy module, may distinct it among the other nodes. The Following fig. 11 shows the structure of the network after complete cover the network. The red node show cluster-head and green ones are those which are connected to cluster-head and blue line show route send data from cluster head to sink.

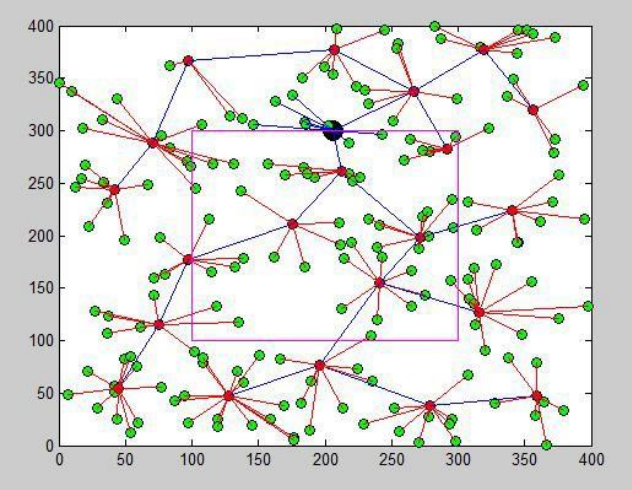

Fig. 11 A typical response of the proposed algorithm

5. Simulation and Results

We have simulated the proposed algorithm and other protocols with the MAT- LAB software. We will compare the CFMTL algorithm with LEACH [4], Fuzzy [7], GA [8] and FGA [9]. The parameters considered in this simulation are given in Table 4.

Table 4: Simulation parameters

Parameter	Value
Initial energy for node	0.1 *Joule*
E_{elect}	50 *nJ/bit*
E_{fs}	10 *pj/bit/m*^{2}
E_{mp}	0.0013 *pj/bit/m*^{4}
E_{DA}	5 *nj/bit/signal*
dco	87*m*

5.1 First-dead Node (FDN) Compare

Table 5 displays the dead time of the first node in the proposed algorithm and other methods in different environments.

Table 5: First-dead for change network size and number of nodes

Algorithm Type					
Network Parameters	LEACH	Fuzzy	GA	FGA	CFMTL
150 node with network size : 250*250	78	92	118	150	338
150 node with network size : 250*250 200 node with network size : 400*400	15	17	42	95	253

5.2 Consume Energy

In figure 12, we have compared the proposed algorithm with other methods in terms of reduction rate of the networks energy. As can be clearly seen, our algorithm has made the reduction rate of the networks energy much smoother and more uniform compared with other methods.

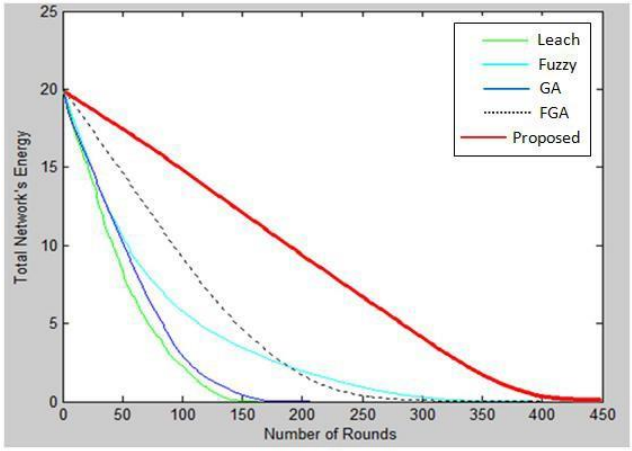

Fig. 12 The reduction rate of network energy network size: 400*400, number of nodes: 200

5.3 Number of Alive Nodes

Improving performance of the algorithm in terms of increased network lifetime compared with other methods is shown in figure 13. As can be seen, the proposed algorithm has increased the death time of the first node in comparison with other methods. Even after the death of the first node of the network, if the network will be allowed to proceed until all of the networks nodes consume their

energy, we can observe that even after the death of the last node, the number of the periods spent would still be higher.

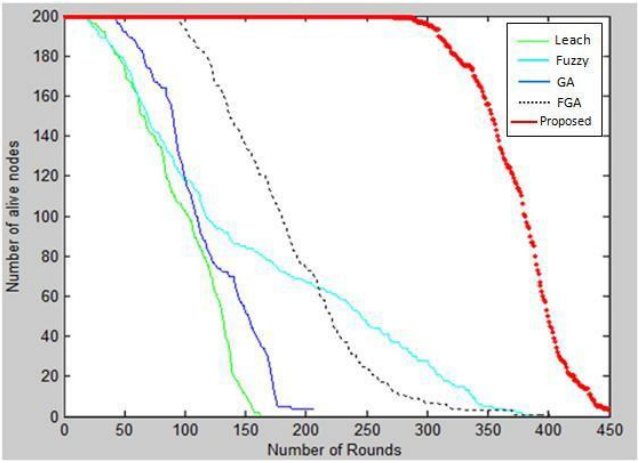

Fig. 13 Compare the number of live nodes in the network size: 400*400, number of nodes: 200

6. Conclusion

Optimum energy consumption in wireless sensor networks is of great importance, so that optimum consumption of energy leads to increasing networks lifetime. An efficient routing technique is known as hierarchical routing based on clustering that prolongs the network lifetime.

In this paper, the most priority cluster heads were selected via a three-level fuzzy logic. In the first level the priority nodes were selected based on their residual-energy and density. Then, in the second level, nodes overall cooperation is considered according to centrality, proximity to BS and distance between CHs in the whole network. In the third level, the sink is move based on two parameters energy of cluster heads and distance of cluster heads to sink. The proposed algorithm was compared with similar approaches LEACH [4], Fuzzy [7], GA [8] and FGA [9] in energy consumption and number of live nodes. The performance of the algorithm was evaluated by a simulation and the results showed that in this approach, nodes consume less energy and live longer. Moreover, a fair load distribution and hence fewer variance of energy consumption demonstrate the efficiency of the proposed algorithm.

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