Fussy Re-clustering for Routing in Wireless Sensor Networks

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ABSTRACT: *In Wireless Sensor Networks (WSNs) where nodes are energy constrained, power conservation is an important issue. This paper proposes a novel approach for energy efficient clustering technique using the fuzzy logic method. The clustering technique has been proven effective to optimize the energy consumed by the nodes of a wirelesssensor network during data routing.*

The establishment of clusters, the cluster-heads choice, and the manner in which the clusters evolve over time are difficult tasks that greatly affect the quality of the routing protocol.

The objective of this protocol is increasing the lifetime of sensor nodes by re-clustering the whole network repeatedly using on a fuzzy re-clustering system model.

Keywords: Wireless Sensor Network, Routing Protocol, Reclustering Process, Fuzzy Logic

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1. Introduction

There are many fundamental problems that sensor networks research will have to address in order to ensure a reasonable degree of cost and system quality, such as the energy consumption.

Experiments done on routing protocols for WSNs have shown that the energy dissipated by the transmission unit of a node may reach half of the total consumption [1]. And, according to [2] the cost of transmitting one information bit is approximately the same as the cost required to calculate a thousand of operations. These studies lead to the need to reduce the number and the distance of communications between nodes to allow them to keep their energy, and consequently increase the network lifetime.

The following equations show the relationship between the communication distance and the energy consumed by a transmitter or receiver node. When the distance between the transmitter and the receiver is less than a threshold value $\boldsymbol{d_0}$, the radio model adopted is the free space model:

When $d < d_0$

$$E_{Tx}(k, d) = E_{elec} * k + \varepsilon_{fs} * d^2$$

When $d >= d_0$, the radio model adopted is the multi-path fading channel model :

$$E_{Tx}(k, d) = E_{elec} * k + \varepsilon_{mp} * d^4$$

$$E_{Rx}(k) = E_{elec} * k$$

The effectiveness of the clustering technique in extending the network lifetime has been proved in several studies, such as **LEACH** [4] and its improvements like **LEACH-C**.

Indeed, the division of the network into groups of nodes, clusters, and the cluster-head election decreases considerably the network load. Then, it allows the nodes to keep longer their energies thanks to the minimization of distance communications.

The clustering mechanism is energy-efficient when its progress is well managed in terms of size and number of clusters, the selection criteria of cluster-heads, and the frequency of re-clustering of the whole network.

The fuzzy logic, a multi-valued logic, is appropriate for this context. It can be used to perform the clustering process and the choice of the suitable cluster-head.

It gives the possibility to define intermediate values other than the conventional ones like yes/no, true/false. Fuzzy logic applies a human-like way of thinking on computer programs.

The remainder of this paper is organized as follows: **Section II** is devoted to the related work, **section III** presents the proposed fuzzy re-clustering process. In **Section IV** we present the simulation results.

Conclusion of the paper is given in **Section V**.

2. Related Work

According to the **LEACH** protocol, the process of reclustering is performed periodically. The cluster-head selection is done according to a probabilistic law. During each cycle, each node selected a random number between 0 and 1. If this number is below a threshold, the node becomes a cluster-head for the current cycle.

In [3], authors use a fuzzy inference system for the clustering process to improve the **LEACH** protocol.

This approach while it minimizes energetic consumption but it asks the nodes for more calculations and communications to get the data about nodes' density and their distances to the base station [3].

[5] Presents a fuzzy logic luster-head selection. Authors use for their fuzzy system model three input parameters: distance of cluster centroid, remaining battery power of sensor, and the network traffic [5]. The problem is that it is not obvious for a node, even the sink, to get the level of network traffic.

Having these parameters requires for a sensor node much energy, and overloads the network with control packets.

Into the same context, another approach called **E**nergy- **A**ware **U**nequal **C**lustering with **F**uzzy (**EAUCF**) has been introduced to maximize the network lifetime [6].

This unequal clustering approach is based on the fact that the closest Cluster-heads to the base station deplete quickly their energy. The solution was to reduce the size of the clusters gradually as the cluster-head energy decreases, which may have nodes not covered by clusters; unclustered nodes. To calculate the competition radius, they use tow fuzzy input variables; the distance to the base station, and the residual energy of the tentative cluster-head [6].

Authors of [7] introduce a fuzzy approach to energy optimization routing for wireless sensor network. As they focused on

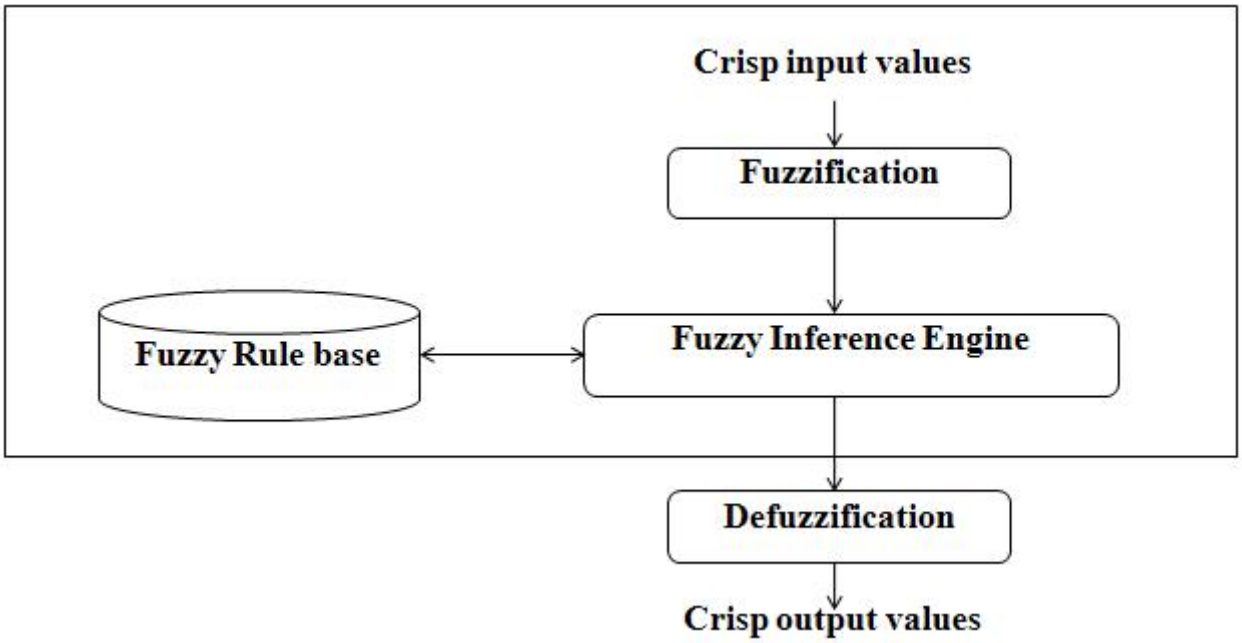


Figure 1. FIS Architecture

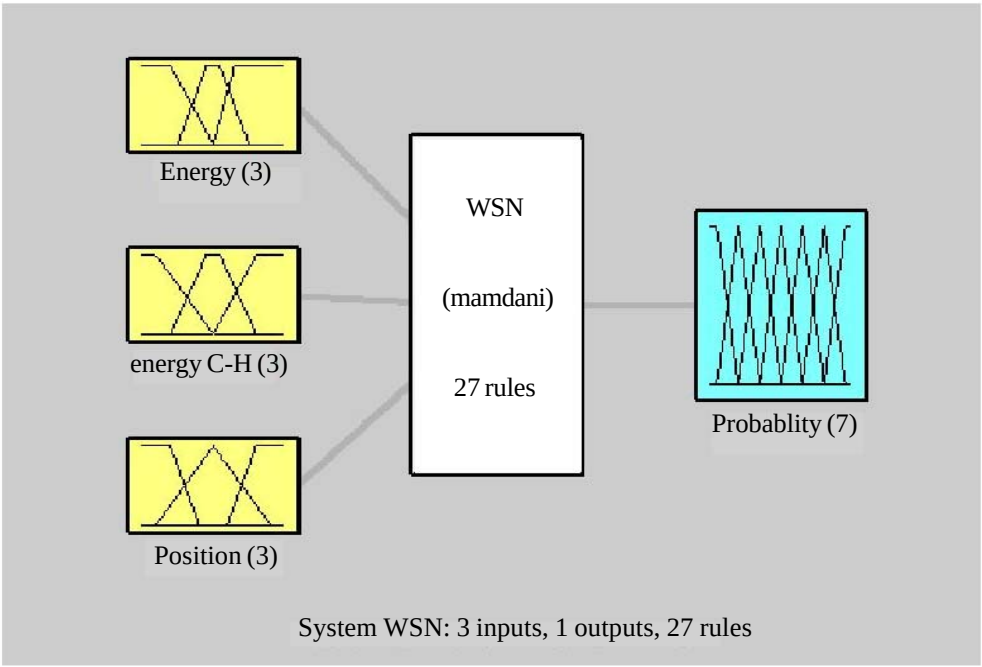


Figure 2. Fuzzy re-clustering System Architecture

effective energy optimized routing within cluster, they have not considered the issue of cluster formation, routing between cluster-heads, and energy optimization of cluster-heads.

The output of their fuzzy model is the cost of link between any two sensor nodes. The input fuzzy variables are: transmission energy, remaining energy, rate of energy consumption, queue size, distance from gateway and weight of a node.

The major weakness of this approach is the hypothesis stating that Cluster-heads are unlimited energy nodes.

Parameter	*Term sets*
Energy	Low, medium, high
Energy C-H	Low, Medium, High
Position	Near, Medium, Far Very weak, Weak, Little
Probability	weak, Medium, Little strong, Strong, Very Strong

3. Fuzzy Re-Clustering System Model

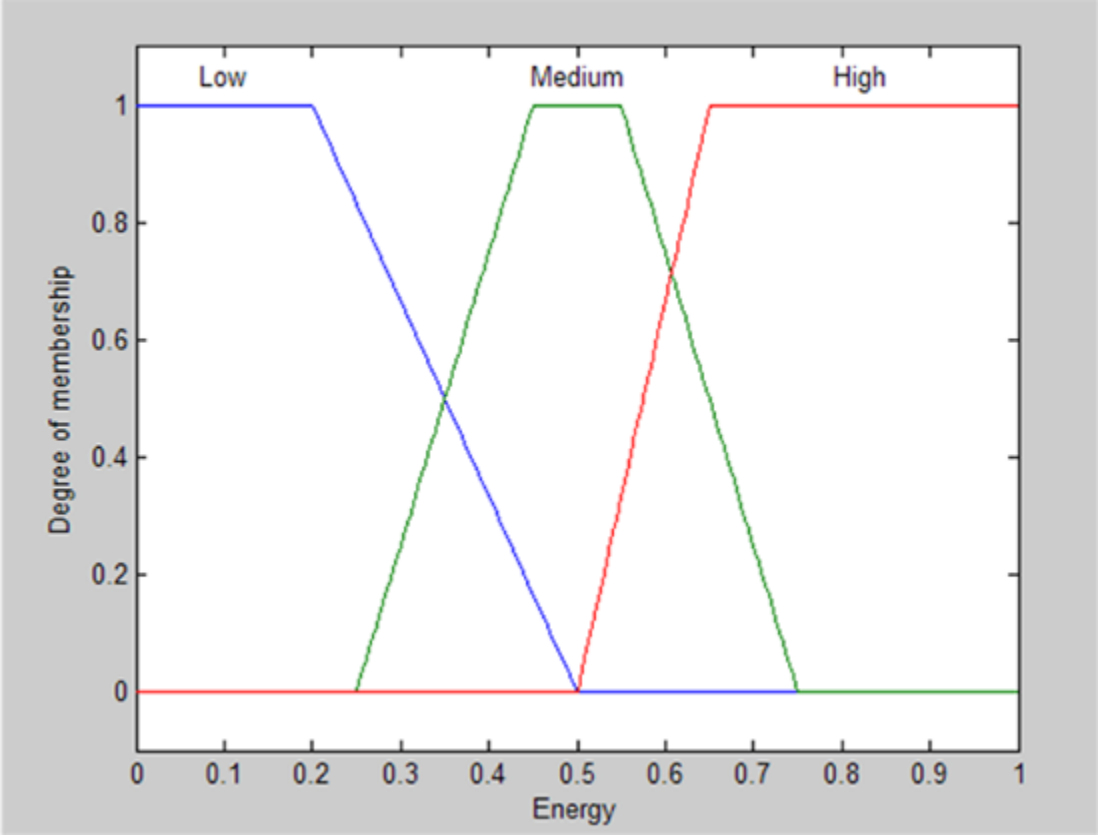
The fuzzy logic is based on four parts shown through the following figure:

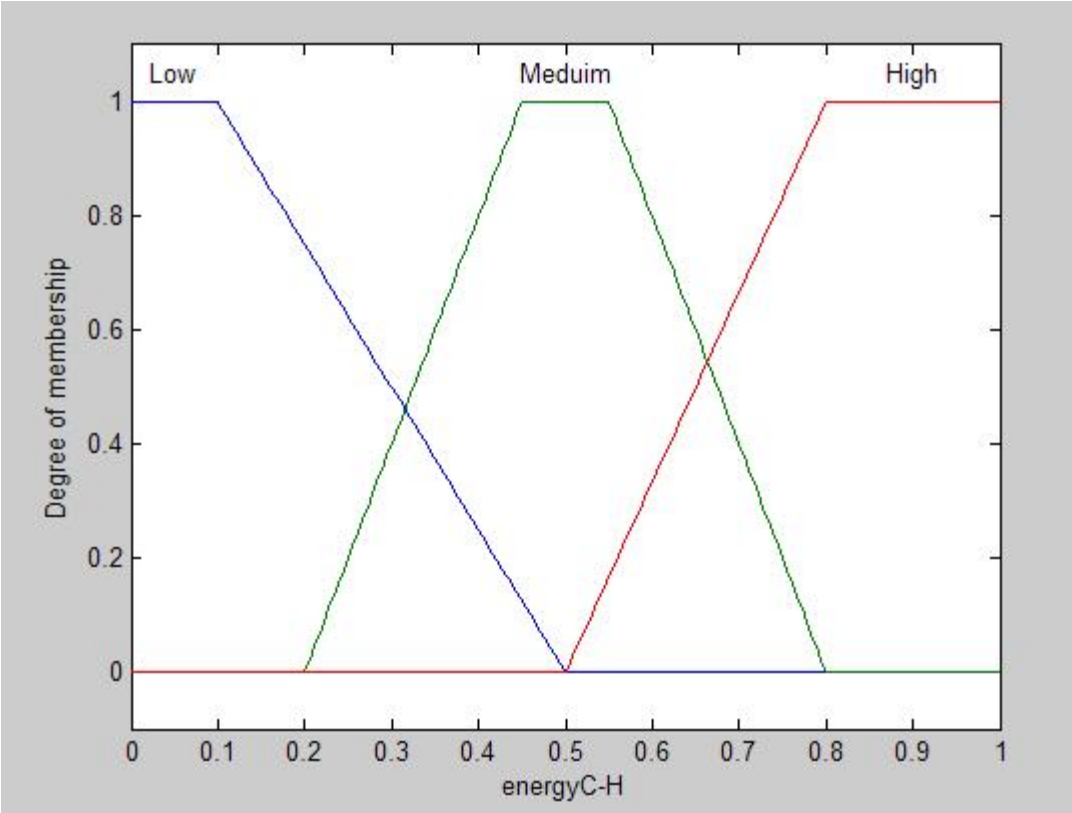
- **Fuzzy rule base:** it is a store of **IF-THEN** rules.
- **Fuzzy Inference Engine:** applies reasoning to compute fuzzy outputs.
- **Fuzzification module:** translates crisp inputs into fuzzy values.
- **Deffuzification:** translates fuzzy outputs into crisp values

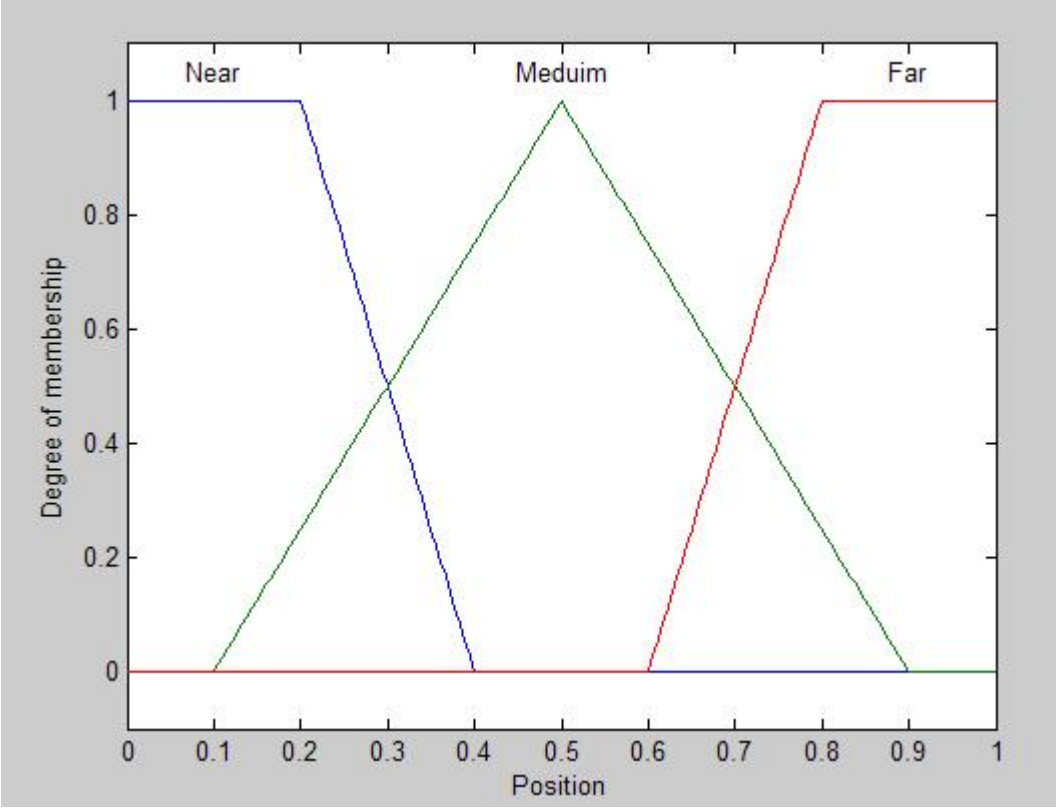
Initially the network is divided into **N** cluster, such as **N** is **5%** of the total number of nodes. In cases where cluster-head is so far to the base station, a node located at the edge of the cluster can act as a relay.

The fuzzy module will be executed to change the roles of the nodes. After some time, the nodes must not retain their original roles to avoid exhausting their battery.

The frequency of execution of the re-clustering process depends on the type of application for which the **WSN** will be used.




Low
Meduim
High
Degree of membership
energyC-H
0
0.2
0.4
0.6
0.8
1
0.1
0.3
0.5
0.7
0.9


Near
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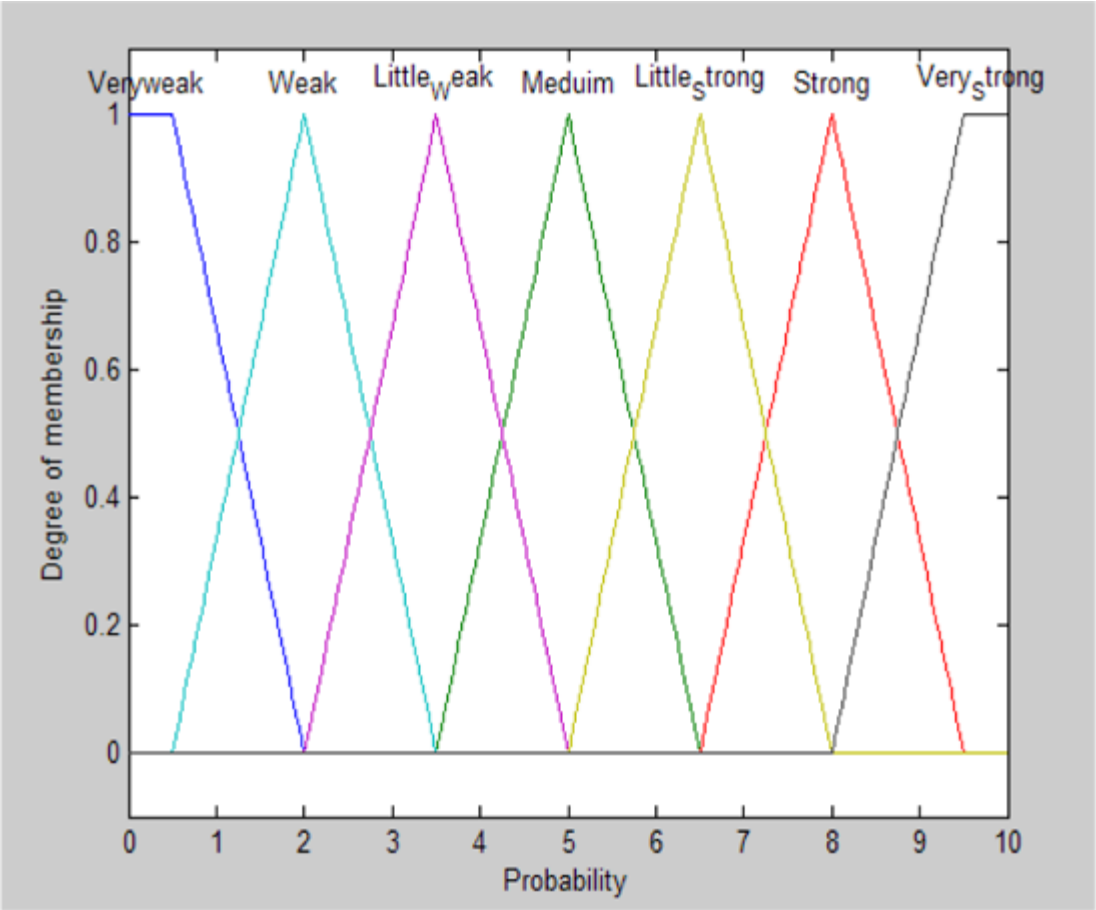


Figure 3. Fuzzification functions (energy, energy C-H, position, probability)

Only cluster members are expected to perform the fuzzy process to decide if everyone becomes a cluster-head or not for the next cycle.

3.1 Fuzzification module

In order to get optimal clusters-head, we need to take into account the energy of the current cluster-head, the energy of the future cluster-head and its position relative to the current Cluster-Head. These parameters are the inputs of our Fuzzy system.

For each input function we have three membership functions.

As shown in the following figures, as we use triangular and trapezoidal membership function.

The input parameters for the **FRCS** (**F**uzzy **R**e-**C**lustering **S**ystem) are:

- The remaining energy in the node (energy)
- The remaining energy in the current cluster-head (energy C-H)
- Distance to the current cluster-head (position)

The linguistic parameters and their term sets are shown in table1.

3.2 Rules base

The rules have the following form in Table 2.

***IF* A *and* B *and* C *then* D**

Energy	Energy C-H	Position	Probability
Low	Low	Near	Weak
Low	Low	Medium	very weak
Low	Low	Far	very weak
Low	Medium	Near	very weak
Low	Medium	Medium	very weak
Low	Medium	Far	Very weak
Low	High	Near	Very weak
Low	High	Medium	Very weak
Low	High	Far	Very weak
Medium	Low	Near	Very strong
Medium	Low	Medium	Little strong
Medium	Low	Far	Medium
Medium	Medium	Near	Little strong
Medium	Medium	Medium	Medium
Medium	Medium	Far	Little weak
Medium	High	Near	Medium
Medium	High	Medium	Little weak
Medium	High	Far	Weak
High	Low	Near	Very strong
High	Low	Medium	Strong
High	Low	Far	Little strong
High	Medium	Near	Strong
High	Medium	Medium	Little strong
High	Medium	Far	Medium
High	High	Near	Little weak
High	High	Medium	Weak
High	High	Far	Very weak

Table 2. Rules

A, **B**, **C** and **D** represent respectively energy of the node, energy of the current cluster-head, the position of a node relative to the current cluster-head.

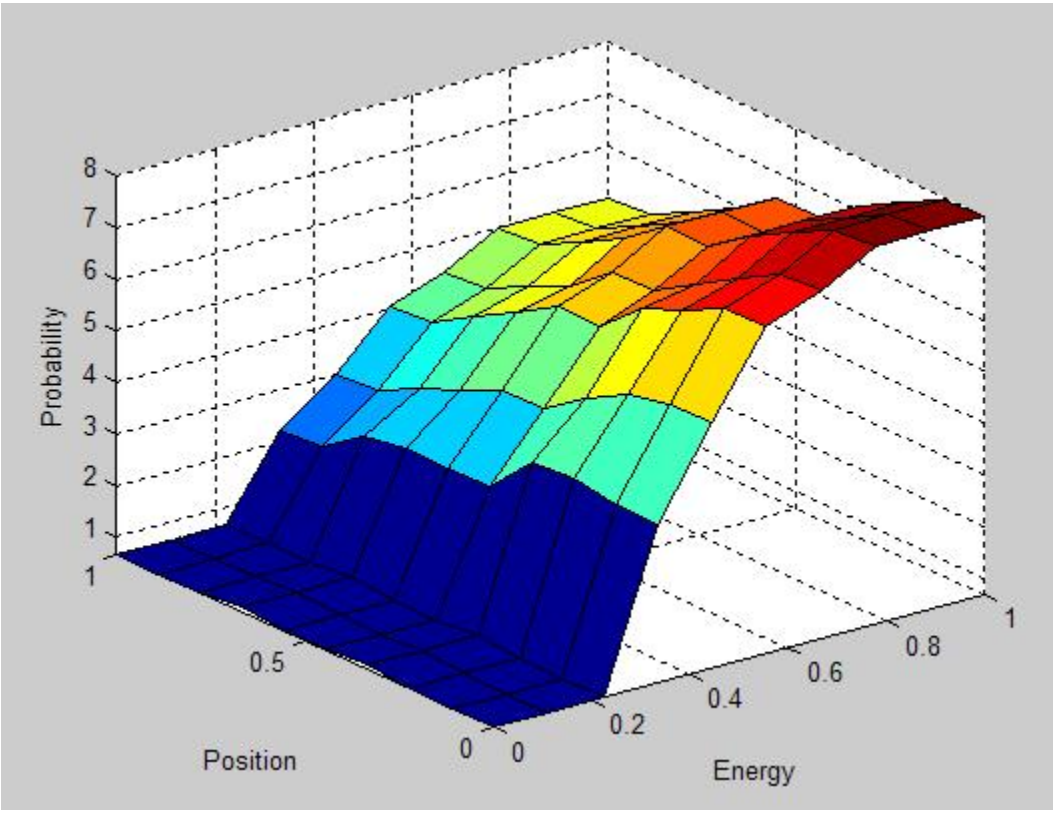
In the fuzzy inference we have 27 rules.

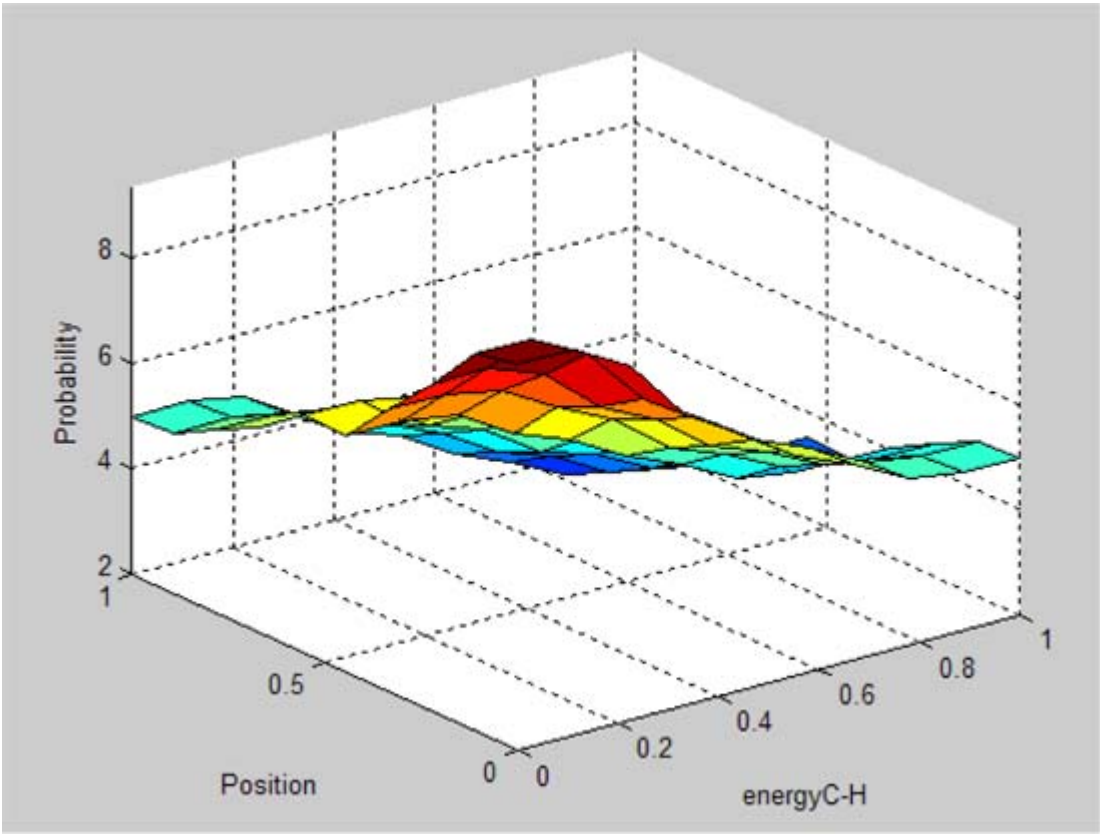
3.3 Defuzzification module

For the defuzzification module, several methods can be used, such as the centroid. It is the most popular deffuzification methods. It returns the center of the area under the fuzzy set obtained after aggregating conclusions.

4. Results and Discussion

Figure 4 (the three following figures) shows that the three attributes of the nodes have different effect on the probability for a


Probability
8
7
6
5
4
3
2
1
1
0.5
0
Position
0
0.2
0.4
0.6
0.8
1
Energy


Probability
8
6
4
2
1
0.5
0
Position
0
0.2
0.4
0.6
0.8
1
energyC-H

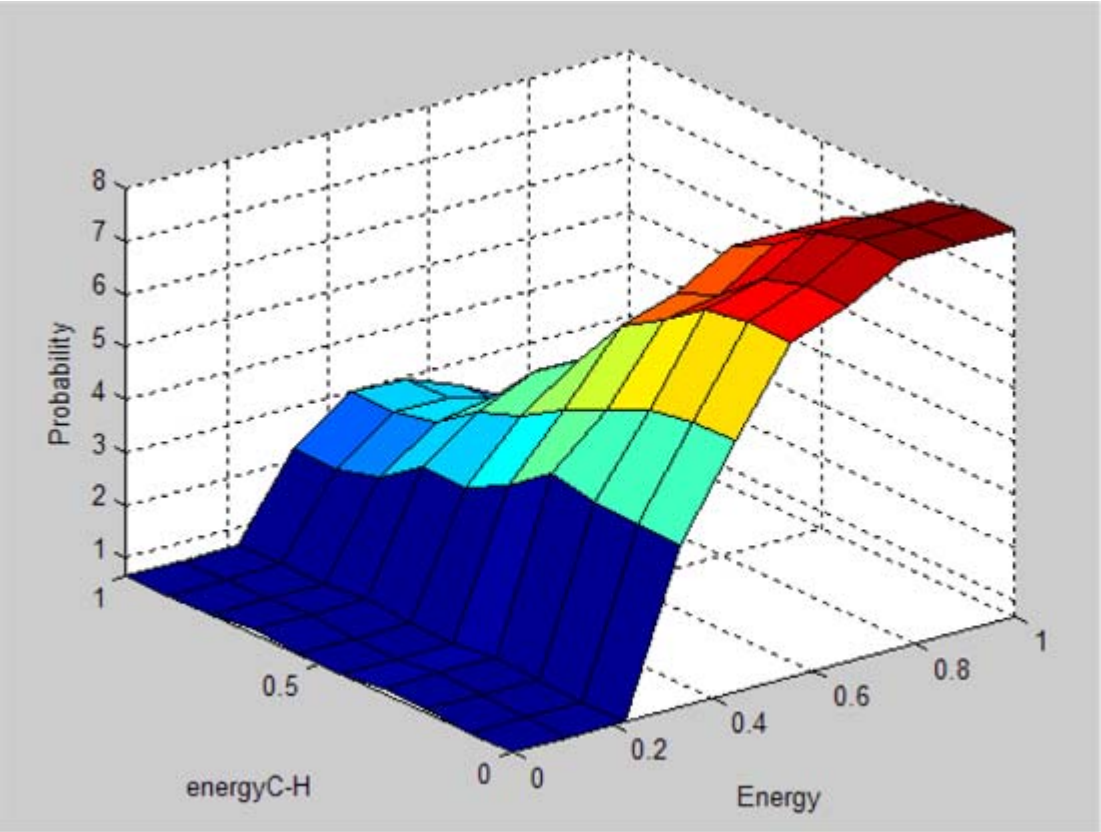


Figure 4. Surface

node to be a cluster-head.

While the energy remaining in a node is greater than a minimum threshold and its position is near to the current cluster-head, its probability to be selected as a cluster-head increases.

With the increase of the current cluster-head energy, the probability for a member node to be a cluster-head decreases.

The probability of a member node to become cluster-head increases as its position is closer to the current Cluster-head, and the energy of the latter decreases.

5. Conclusion

Clustering technique has appeared as popular approach network architecture in WSNs. Its mechanism helps to reduce the complexity of network overhead which is proportional to the number of nodes in the network.

In this paper we studied the contribution of the use of modeling with fuzzy logic in the clustering process.

Since the criteria for selecting clusters and the way in which clusters evolve throughout the life of the network closely affect the routing protocol performances and therefore the energy consumption, the clustering process must be carefully treated.

Fuzzy logic is seen suitable for this treatment. The input variables of our fuzzy model are the position of a member node, likely the future Cluster-head, relatively to the current luster-head, its residual energy, and the residual energy of the current Cluster-head.

Taking into account the residual energy of the current Cluster-head allows the use of all of its energy without loss. While

considering the residual energy of a future Clusterhead avoids having a cluster head with insufficient energy.

And finally, checking the position relative to the current Cluster-head eliminates the possibility of having unclustered nodes.

The output of our fuzzy model is the probably for a member node to become a Cluster-head.

This fuzzy model allows an increase in the network lifetime based on the re-clustering criteria.

References

[1] Chook, V., Chessa, S., Gotta, A., Hu, V. F., Baronti, P., Pillai, P. (2007). wireless sensor networks: a survey on the state of the art and the 802.15.4 and zigbee standards.

[2] Gregory J. Pottie, Kaiser, W. J. Wireless integrated network sensors. *Communications of the ACM*.

[3] Ran, G., Zhang, H., Gong, S. (2010). Improving on LEACH protocol of Wireless Sensor Networks using Fuzzy Logic, *Journal of Information and Computational Science*, p. 767 - 775.

[4] Balakrishnan, H., Heinzelman, W., Chandrakasan, A. Energy-efficient communication protocol for wireless micro sensor networks. *In*: proc of the Hawaii International Conference on Systems Science.

[5] Anno, J., Barolli, L., Xhafa, F., Durresi, A. (2007). A cluster head selection method for Wireless Sensor Networks based on Fuzzy logic. IEEE.

[6] Bagci, H., Yazici, A. (2013). An energy aware fuzzy approach to unequal clustering in ireless Sensor Networks. T*he Official Journal of the World Federation on Soft Computin*g (WFSC).

[7] Haider, T., Yusuf, M. (2009). A Fuzzy Approach to Energy Optimized Routing for Wireless Sensor Networks. *The International Arab Journal of Information Technology*, 6 (2), April.