ISSN 2047-3338

F-MCHEL: Fuzzy Based Master Cluster Head Election Leach Protocol in Wireless Sensor Network

Tripti Sharma[1] and Brijesh Kumar[2]

[1]Department of Information Technology, Maharaja Surajmal Institute of Technology, New Delhi, India

[2]Department of Information Technology, Lingayas University, Faridabad, India

***Abstract*– Wireless Sensor Network is the network of power-limited sensing devices called sensors deployed in a region to sense various types of physical information from the environment when these sensors sense and transmit data to other sensors present in the network; considerable amount of energy is dissipated. In this paper, an effort has been done to propose F-MCHEL, a homogeneous energy protocol. In LEACH protocol the clusters are formed randomly on the basis of threshold values; whereas, in the proposed protocol a fuzzy logic approach is used to elect the cluster-head based on two descriptors - energy and proximity distance .Out of these elected cluster heads one Master cluster head has been elected .The cluster head which has the maximum residual energy is elected as Master cluster head. In conventional Leach approach all the Cluster heads are used to sends the aggregated information to the base station, however in the proposed protocol only Master cluster head sends the aggregated information to the base station. Simulation results on MATLAB shows that the proposed protocol provides higher energy efficiency, better stability period and lower instability period as compared to LEACH protocol in spite of overhead of election of Master cluster head. Results obtained shows that an appropriate Master cluster-head election can drastically reduce the energy consumption and enhance the lifetime of the network.**

***Index Terms*– Wireless Sensor Networks, Stability Period, LEACH, Fuzzy Logic and Base Station**

I. INTRODUCTION

WIRELESS Sensor Network (WSN) is a system consisting of wireless sensors deployed in a region to sense various types of physical information from the environment. The data sensed by these sensors (or nodes) is then sent to Base Station (BS) for assessment. WSNs are used for variety of purposes like habitat monitoring, military surveillances, forest-fire detections, transport monitoring, etc. Since the nodes are small and wireless, these can be deployed with ease, even in remote areas and hilly terrains. However, the numbers of such nodes are considerably high and monitoring these nodes is quite difficult, especially in the cases when the nodes are distributed in the regions far away from a city or town. The network once established, keeps on sensing the data and the energy of the nodes keep on dissipating whenever, they receive some information and send it further to other nodes or BS.

A number of routing protocols have been proposed to make nodes more energy efficient. There are cases that the nearby nodes sense the same data and transmit it to BS, making network inefficient. It is found that to maintain worthy information at the BS, the nodes must be responsible for data aggregation and fusion. So, a reliable network is the one in which the redundant information is negligible. To avoid redundancy, clustering algorithms were proposed. The whole network of nodes is divided into a number of clusters; the data aggregation is performed within the cluster and then transmitted to the BS. Clustering helps in reduction of redundancy and improvement over the lifetime of the network. The LEACH [1] and SEP [2] are such clustering protocols. In the proposed protocol an improvement has been suggested over CHEF [7], which results in better election of the cluster head (CH). The simulation results show that there is an improvement over stability period of the network and efficient utilization of energy in the case of homogeneous environment.

The rest of the paper is organized as follows: Section 2 depicts the review of the related work in the field of wireless sensor clustering protocol. Section 3 will describes the energy model that has been used in the proposed protocol. Section 4 defines the proposed protocol F-MCHEL and its phases. Section 5 contains simulation results and the comparison of the suggested protocol with the existing LEACH and CHEF protocol. Finally, section 6 illustrates the conclusion and the future works for further improvement.

II. RELATED WORK

A lot of study has been done to minimize the energy used in routing and number of protocols has been developed. These protocols can be classified as - Hierarchical, data centric, location based and Network flow protocols. In this paper, we are particularly focusing on hierarchical protocols. In such types of protocols, the energy efficient clusters are formed with a hierarchy of cluster heads. Each cluster has its representative cluster head which is responsible for collecting and aggregating the data from its respective cluster and then transmitting this data to the Base Station either directly or through the hierarchy of other cluster heads.

The existing hierarchical protocols are:

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH [1] is one of the most popular clustering algorithms. The main idea behind LEACH is to form clusters based upon the signal strength of the sensors. Some of the nodes are randomly chosen as the cluster heads(CH) and a node is assigned to the CH based upon the signal strength received by that node from the CH. CHs have to do a lot more work than the s, hence they dissipate a lot more energy and may die quickly. In order to maintain a stable network, CHs keep on rotating, in every round. So, a node which had become CH may not get an opportunity to become CH again before a set interval of time.

A node can become the cluster head for the current round if its value is less than the threshold T(n) where T(n) [1] is given by:

$$T(n)=\begin{cases}\dfrac{P}{1-P*(r \bmod \frac{1}{P})} & \text{if } n \in G\\ 0 & \text{otherwise}\end{cases} \quad (1)$$

P is the percentage of cluster heads, r is the rth round, and G is the set of nodes which are not cluster heads in the last 1/P rounds. Figure 1 shows how clusters are formed in 100*100 region in one round. Nodes having same symbol belong to the same cluster. The cluster heads are shown in red. Base Station (or sink) is situated at (50, 50) and is shown by X.

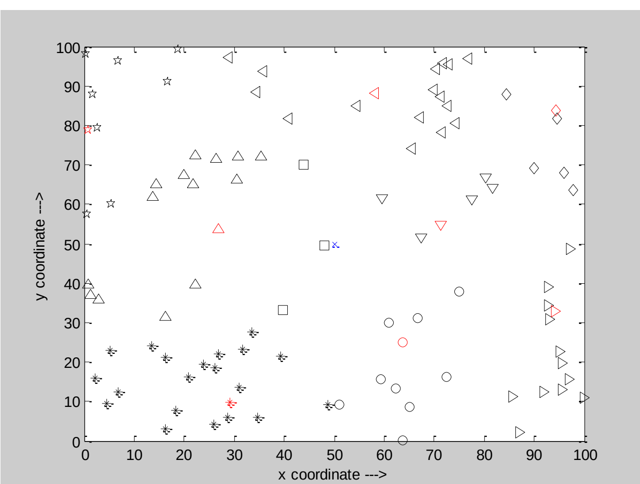

Figure 1: Distribution of Nodes and Formation of Cluster

Compared to direct communication, LEACH achieves 7 times more reduction in energy dissipation and about 4-8 times more reduction as compared to MTE routing protocol [1]. A drawback of LEACH is that LEACH is a single hop routing. Each node transmits its data to either CH or BS directly. Moreover, for a network of larger regions, the dynamic clustering may become overhead since rotation of CH at every round and advertisements of CHs also dissipate energy. LEACH also gives no idea about the placement of nodes and the distribution of clusters is totally randomized.

B. LEACH-C protocol

LEACH-C [3] is a centralized clustering algorithm in which BS has the right to select the clusters based upon the annealing algorithm to find k optimal number of clusters. BS selects the CHs for a particular round. The protocol guarantees optimum clusters but has a drawback that each node sends information about its current location and residual energy to the sink during the set up phase which results in an extra overhead.

C. CHEF (Cluster –head Election mechanism using Fuzzy Logic)

In CHEF [7] chance has been calculated using Fuzzy if-then rules to elect the cluster head (CH). Two variables namely proximity distance and energy are considered as key parameters in calculating the chance. The fuzzy logic based approach allows the node with High energy and locally optimal node to elect as a cluster head. The CHEF is 22.7% more efficient than LEACH.

III. ENERGY MODEL ANALYSIS

In this paper, an effort has been done to compare the three protocols – LEACH, CHEF and the proposed protocol F-MCHEL (Fuzzy based Master cluster head election protocol), based on the energy dissipation model shown in the Figure 2.

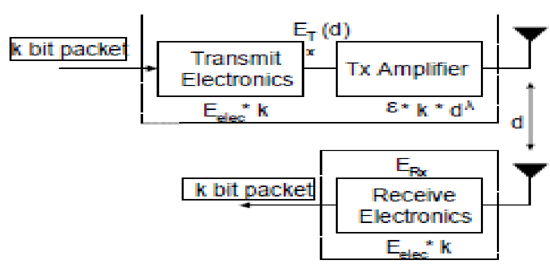

Figure 2: Energy dissipation diagram

For a particular node, the energy is dissipated because of receiving and transmitting.

The energy expanded in transmitter to transmit k-bit message is given by:

$$ET(k,d) = (Eelec * k) + (Efs*k*d^2) \quad \text{if } d<=d0$$
$$(Eelec * k) + (Emp*k*d^4) \quad \text{if } d>d0$$

- Eelec is the energy dissipated to run the electronics circuits
- k is the packet size

- Efs and Emp are the characteristics of the transmitter amplifier
- d is the distance between the two communicating ends.
- Energy dissipation to receive a k-bit message is given by- ER(k) = Eelec* k

The values of radio characteristics are:

Eelec = 50 nJ/bit

Efs = 10 pJ/bit/m2

Emp = 0.0013pJ/bit/m4

In addition to above energy expansions, a CH also dissipates energy because of data aggregation. The data aggregation energy EDA has the value of 5nJ/bit/signal.

IV. F-MCHEL: FUZZY BASED MUSTER CLUSTER HEAD ELECTION LEACH PROTOCOL

In this section F-MCHEL (Fuzzy based Master Cluster Head Election Leach protocol), a homogeneous energy protocol ,has been introduced, which uses fuzzy if -then rules to maximizing the lifetime of WSNs. F-MCHEL is similar to the CHEF [7] but it has the Master cluster head election mechanism. Cluster heads election process is similar to CHEF [7]. In CHEF the cluster head has been elected using the fuzzy approach based on two input parameters namely, Energy of the node and Proximity distance. In CHEF all the elected cluster heads are used to send the aggregated information to Base station, whereas in F-MCHEL one Master cluster head has been elected out of these elected cluster heads. Cluster head node which has the maximum residual energy is elected as Master cluster head. After the formation of clusters all non-Cluster heads nodes are used to sends the information to the respective cluster head.

All Cluster head will aggregate the information received from non-Cluster head nodes and they send the aggregated information to Master cluster head.

Master cluster head again aggregate the information received from cluster heads and sends this information to Base station. Like LEACH and CHEF, the proposed protocol F-MCHEL also assumes two phases at the beginning of each round, one is the setup phase and other is the steady state phase, which is explained below:

A. Setup Phase

In setup phase, CHs are identified and clusters are formed. The cluster heads are chosen on the basis of fuzzy if –then rule and two input parameters Energy of the node and Proximity distance [7].

1) Fuzzy Inference System

The process of Fuzzification requires a complete architecture of its own, known as the Fuzzy Inference System (shown in Fig. 3).

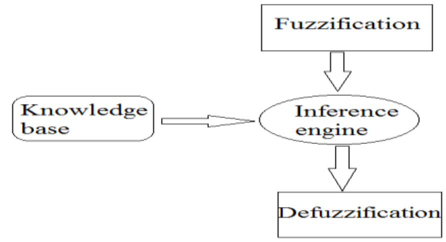

Figure 3: Fuzzy Inference System

1 Fuzzification module: This module is required to transform the system inputs, which are crisp numbers, into fuzzy sets. A Fuzzification function has to apply to accomplish this.

2. Knowledge base: It stores the IF-THEN rules.

3. Inference engine: The engine makes use of the inputs and IF-THEN rules to simulate reasoning by producing a fuzzy inference.

4. Defuzzification module: It transforms the fuzzy set obtained by the inference engine into a crisp value.

2) Fuzzification Module

Two different parameters namely Energy and Proximity distance has been used to determine the cluster heads [7].

- Energy– remaining energy of the node.
- Proximity Distance- the sum of distances between the node and the cluster head within a certain radius.

These two parameters are here known as Input Functions. There are three different membership function associated with each input function. Table 1 shows the input function and their respective membership functions.

Table 1: Input Functions

Input	Membership		
Energy of Battery	Low	Medium	High
Proximity Distance	Near	Medium	Far

Chance has been considered as the output function. It has 9 different membership functions. Table 2 shows the output function.

Table 2: Output functions

Output	Membership Function
	Very low, Low, Little low, Lower medium, Medium, Higher medium, Little high, High, Very high

3) Knowledge Base and Inference Engine

The 9 different rules have been used as shown in Table 3 in the fuzzy inference for 9 different membership functions of the output function. The energy and the proximity distance are used to calculate the chance [7].

The form of the rules is: If P and Q THEN R. P, Q and R represent battery level, proximity distance and chance respectively. The energy of battery is the key for the probability of cluster heads election [7]. Now the proximity distance is the sum of distances between the node and the cluster head which is within r distance. Here r is the average radius of the cluster in consideration and is given by r as in CHEF [7].

$$r = \sqrt{\frac{area}{\pi \cdot n \cdot P}}$$

Where n is the total number of nodes present in the WSNs. The proximity distance is calculated in the same manner as in CHEF [7].

4) Defuzzification Module

To get the crisp values, defuzzification method is required. Here the technique of centroid is used. This technique finds the centre of the area under the fuzzy set obtained aggregating conclusions [9].

The centroid defuzzification technique can be expressed as

$$x = \frac{\int x \cdot \mu_{chance}(x)\, dx}{\int x\, dx}$$

Where x is the defuzzified output, $\mu_{chance}(x)$ is the aggregated membership function and x is the output variable. The only disadvantage of the centroid technique is that it is computationally difficult for complex membership functions.

Table 3: Rules

Energy of Battery	Proximity Distance	Chance
Low	Far	Very low
Low	Medium	Low
Low	Near	Little low
Medium	Far	Lower medium
Medium	Medium	Medium
Medium	Near	Higher medium
High	Far	Little high
High	Medium	High
High	Near	Very High

B. Steady State Phase

This phase allows data sensed by the nodes to be transmitted to CHs. The information is transmitted, received and aggregated by the CHs and transferred to Master cluster head for processing. The energy of nodes is dissipated in this phase only. The duration of the steady phase is longer than that of the setup phase to minimize overhead.

The energy dissipation of Cluster head, Master cluster head and non-CH in a round are:

$$E\ (MCH) = E_T(k,d_{to\ BS}) + E_R(k) + EDA \quad (2)$$

$$E\ (CH) = E_T(k,d_{to\ MCH}) + E_R(k) + EDA \quad (3)$$

$$E\ (non\text{-}CH) = E_T(k,d_{to\ CH}) + E_R(k) \quad (4)$$

Base Station is assumed to have infinitesimal energy and hence, no energy is dissipated when BS receives data from the wireless nodes. The Formation of cluster head and the information transmission by Master cluster head has been shown in the Figure 4.

The dotted circles show the clusters. In Figure 4 five clusters has been formed. The solid circle represents all the wireless sensor nodes placed in the network area. The yellow filled circle shows the cluster head corresponding to each cluster and red filled circle represents the Master cluster head. Solid thick line shows the transmission of information from cluster head to Master cluster head and from Master cluster head to Base Station. The arrow with in the cluster from node to CHs shows the local distance between the cluster head and all the nodes with in radius r.

The summation of this local distance is equal to the proximity distance [7]. It is calculated in the same manner as in CHEF [7]. It is clear from the Figure 4 that only the elected Master cluster head sends the data to the Base station and not more than one cluster head can lies within the radius r. In every round cluster heads and a Master cluster head has been elected but only the Master cluster head transmit the aggregated and processed information to the Base station.

The clustering algorithm for the F-MCHEL is given below:

Clustering Algorithm

1/*for every round*/
2. Compute the chance of every node using Fuzzy if-then rule.
3. Choose maximum chance node as CH.
4. Choose Kopt cluster heads (CHs) in every round.
5. Select maximum residual energy cluster head as Master cluster head.
6. All non-cluster head node sends data to kopt cluster heads.
7. /*For Kopt cluster*/
8. All cluster head sends aggregated data to Master cluster head.
9. /* End of for*/
10. Master cluster head sends information to Base station
11. /* End of rounds*/

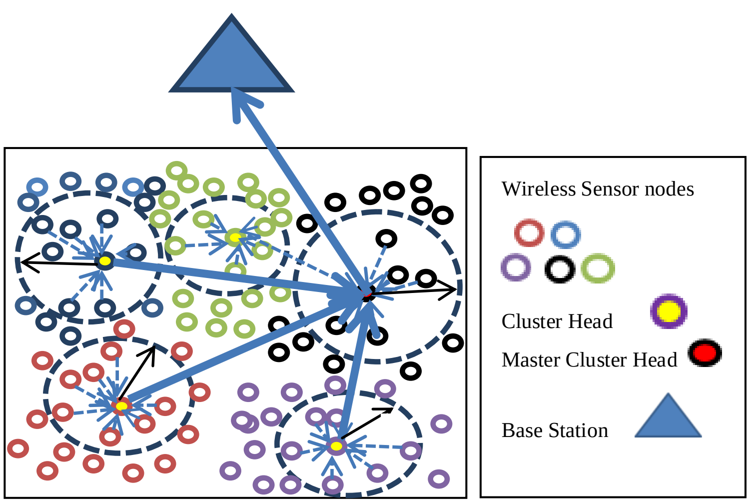

Figure 4: Formation of Cluster and election of Master cluster head

V. SIMULATION RESULTS

Number of experiments has been carried out to compare the three protocols LEACH, CHEF and F-MCHEL with same network and parameter settings. Simulation results on MATLAB depict that F-MCHEL has better stability period and less energy dissipation per round. Simulation results shows that the Fuzzy logic systems, which can manipulate the linguistic rules in a natural way, can avoid the necessity of accurate representation of the environment, which generally does not exist in reality.

A) Network Settings

We are using a 100*100 region having 100 sensor nodes placed randomly. The packet size is considered to be of 2000 bits. The various parameter values taken for experiments are shown in the Table [4].

Table 4: Values of parameters for simulation

Parameter	Value
E_{elec}	50 nJ/bit
Efs	10 pJ/bit/m^2
Emp	0.0013 pJ/bit/m^4
EDA	5 nJ/bit/packet
E_0	0.5 J
K	2000 bits
Kopt	5
Popt	0.05
N	100
Network size	100*100
Base Station Location	(50,175)

Performance of the suggested protocol has been measured on the basis of following parameters:

(i) Stability Period: Stability period is the period (or round) up to which all nodes are alive. This period lies between rounds 1 to the round at which the first node dies.

(ii) Instability period: Instability Period is the period between the first dead node and last dead node. This period should be kept as small as possible.

(iii) Energy dissipation

(iv) Number of packets transmitted to base station

As compared to CHEF and LEACH, F-MCHEL has an improvement over the stability period as shown in the Figure 5 below. As per the simulation results, the first node dead in LEACH and CHEF are at 1132 and 1457 respectively whereas in F-MCHEL, the first dead is at 1952 which shows an improvement of (33.97%) over CHEF and (72%) over LEACH. The result obtained has been shown in Table 5 and Table 6.The instability period is given by the time between first dead node and last dead node. While calculating instability period, we are considering only those rounds in which some data is transferred to the BS. All those rounds in which no data is transferred to BS are not counted. It is clear from the graph that the unstable region for F-MCHEL shows decline over LEACH, however CHEF shows better unstable region as compare to F-MCHEL.

Table 5: Improvement of stable region

	LEACH	CHEF	F-MCHEL	Improvement over LEACH
First Node Dies	1132	1457	1952	72%

Table 6: Declination of unstable region

	LEACH	CHEF	F-MCHEL	Improvement over LEACH
Instability Period = Last node dies – First node dies	441	176	300	31%

With the passage of rounds, the total energy of all the clusters keeps on dissipating. F-MCHEL gives an improvement over LEACH and CHEF in the energy expansion model as shown in Figure 6. The circular dot represents the first dead node. In F-MCHEL, the packets transmitted to the BS are substantially higher than LEACH and CHEF as shown in Figure 7. The circles represent the round at which the first node dies for each of the protocols.

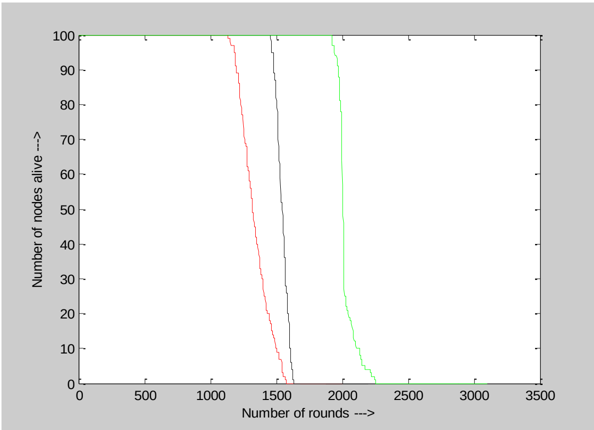

Figure 5: Number of alive s vs rounds

Red (LEACH), Black (CHEF), Green (F-MCHEL)

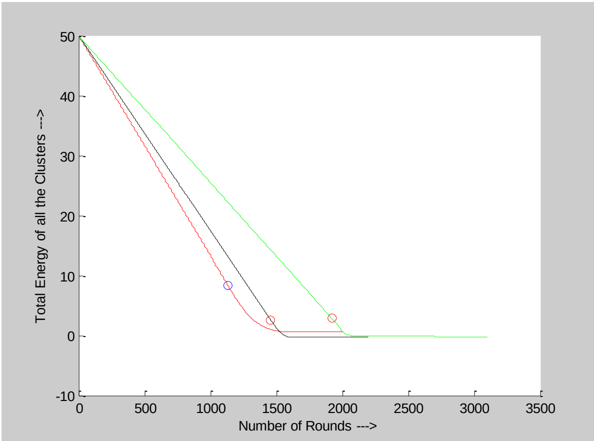

Figure 6. Stable region vs total additive energy

Red (LEACH), Black (CHEF), Green (F-MCHEL)

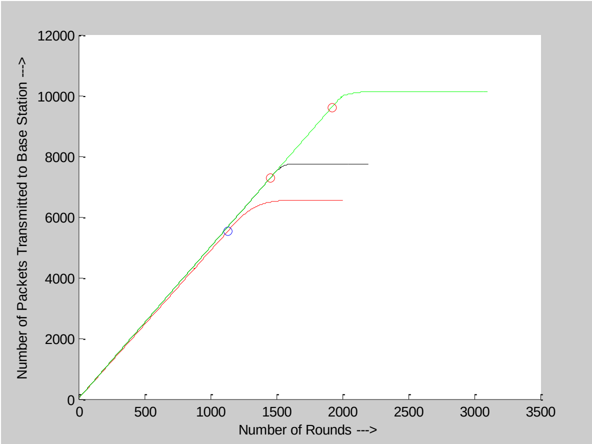

Figure 7: Data received at BS vs Time

Blue (LEACH), Black (CHEF), Green (F-MCHEL)

From the simulations, the following conclusions are obtained for F-MCHEL:

(i) In the homogeneous environment, the stability period is extended as compared to LEACH and CHEF.

(ii) Instability period is reduced as compare to LEACH

(iii) Energy is well distributed among the nodes.

(iv) F-MCHEL is more resilient than CHEF in consuming the Energy

VI. CONCLUSION AND FUTURE WORK

F-MCHEL is an extension of CHEF which results in better stability of hierarchical network as compared to LEACH and CHEF. In this protocol, the clusters are well separated from each other. Simulation results show that F-MCHEL performs better than the existing protocols in homogeneous environments.

In this paper, we have also taken only two parameters as input in homogeneous environment. In the future work effort will be done for measure the performance of the protocol in Heterogeneous environment. The proposed protocol can also be compared with other wireless sensor routing protocols.

REFERENCES

[1] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, Energy-efficient Communication Protocol for Wireless Microsensor Networks., in IEEE Computer Society Proceedings of the Thirty Third Hawaii International Conference on System Sciences (HICSS '00), Washington, DC, USA, Jan. 2000, vol. 8, pp. 8020.

[2] G. Smaragdakis, I. Matta, A. Bestavros, SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks, in: Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), 2004.

[3] W. Heinzelman, A. Chandrakasan and H. Balakrishnan,"An application-specific protocol architecture for wireless microsensor networks," in *IEEE* Transactions on Wireless Communications, Oct. 2002, pp. 660 - 670.

[4] Shio Kumar Singh, M.P. Singh, and D.K. Singh, .A Survey of Energy-Efficient Hierarchical Cluster Based Routing in Wireless Sensor Networks., in International Journal of Advanced Networking and Applications Volume: 02, Issue: 02, Pages: 570-580 (2010)

[5] W.R. Heinzelman, .Application-Specific Protocol Architecture for Wireless Networks. PhD Thesis, Massachusetts Institute of Technology, June 2000.

[6] I. Gupta, D. Riordan and S. Sampalli, "Cluster-head Election using Fuzzy Logic for Wireless Sensor Networks", Communication Networks and Services Rearch Conference, pp.255-260, May 2005.

[7] Jong-Myoung Kim, Seon-Ho Park, Young-Ju Han, Tai-Myoung Chung," CHEF: Cluster Head Election mechanism using Fuzzy logic in Wireless Sensor Networks "ICACT 2008,PP-654-659,feb 2008.

[8] C. Chee-Yee and S.P. Kumar, "Sensor networks: evolution, opportunities, and challenges," in Proc of the IEEE, Aug. 2003, pp.1247 - 1256.

[9] M. Negnevitsky, Artificial intelligence: "A guide to intelligent systems, Addison-Wesley, Reading", MA, 2001.