Parameter based Cluster Head Election in Wireless Sensor Network: A Fuzzy Approach

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ABSTRACT
Wireless Sensor Networks (WSN) is the bunch of thousands sensor nodes because a single sensor node has very limited competence in sensing and isn't sufficient for extracting and transmit useful data. So this process should be competent by using a number of sensor nodes. Wireless sensor network is easily deployed in compare to any other networks because they don't need any particular framework. In wireless sensor network, nodes receive signal from limited area. When this signal is sensed and transmit the information to base station, nodes consume energy. Wireless sensor network contain distinct parameters like energy, processing power and storage. But the energy of nodes is the most important consideration among them. LEACH is one of the prominent proactive sensor network protocols and in this cluster head is selected on the basis of probability of each round, whereas in our proposed method cluster head is selected on the premises of three fuzzy parameters-residual energy, neighbor and centrality. Simulation results for a probability of cluster head on the basis of fuzzy rules using the status of membership function are presented in paper. All the simulation work done in MATLAB.

General Terms
Sensor Network, Fuzzy Rules

Keywords
Fuzzy logic, LEACH, Wireless sensor network, Fuzzy rules

1. INTRODUCTION
Wireless sensor network is a collection of hundred and even thousands of nodes which is called as sensor nodes. Sensor nodes are tiny devices that have the capability of monitoring physical, environment parameter like temperature, pressure, vibration and motion at different locations. Nodes can be deployed in random or deterministic fashion. Wireless sensor nodes are light weight in nature and battery power is used. Wireless sensor network is used in variety of applications like military applications, healthcare, security because it is more useful than wired connection [1]. In wireless sensor network, nodes have to operate unattended for a long time without replacement of power sources, so focus is on optimized use of energy so that the lifetime of the network is increased. Energy utilization is not a important and big issue in traditional wireless network because energy source can be replaced and recharged at any time but energy consumption is a big issue in wireless sensor network. The more energy the node has the more data is processed and transmitted so the lifetime of the node is also longer. The main aim of this approach is to increase the energy level to make network efficient**.**

2. EXISTING METHOD
There are various methods for selecting the cluster head in wireless sensor network. The most popular and first approach was Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is divided into two phases: Set-Up phase and Steady phase shown in fig 1.All the operations of leach are performed in rounds. Each round start with set-up phase, clusters are formed during that time. Once a cluster is formed then data is transfer to the base station in steady phase. Steady phase is normally taken more time compare to set-up phase. The idea of LEACH is to organize the nodes into clusters to distribute the energy among the sensor nodes in the network, and in each cluster there is an elected node called cluster head [3].

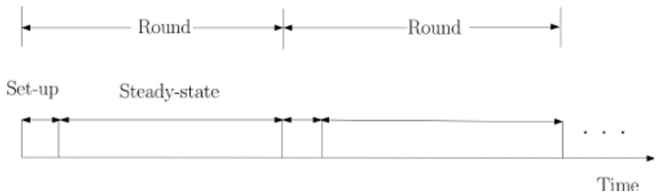

Fig 1: LEACH phases: Start and Steady phases

At the starting of each round each node decide that it has become the cluster head or not. To become a cluster head, each sensor node generates a random number d between 0 and 1. If the value d is smaller than the threshold value T(n) , the sensor node elects itself as a cluster head and advertises this message to other nodes around the cluster head. The main idea behind LEACH is to form clusters based upon the signal strength of the sensors. CHs have to do a lot more work compare to other nodes, hence they dissipate 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. In each round, sensor nodes elect itself as a cluster head based on probability model. The nodes that receive this message calculate the distance between the cluster head and itself and send a join-message to the closest one of the cluster heads to form a cluster. Equation (1) defines the T(n) where p is the requested ratio of the cluster heads in the WSNs and r is the count of current round. The G is the set of sensor nodes that were not elected as a cluster head in last 1/p rounds [2].

$$T(n) = \begin{cases} p/1-p*(r mod 1/p) , & \text{if } n \in G \\ 0 , & \text{otherwise} \end{cases} \quad (1)$$

In LEACH protocol a simple radio system model had been identified which describe the energy dissipation though the electronic devices, transmitter, power amplifier and the receiver. Fig. 3 shows the radio model [3].

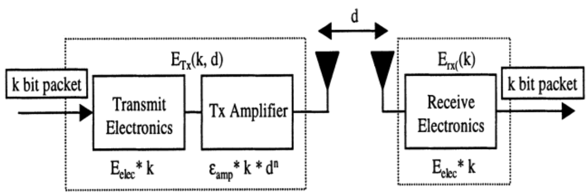

Fig 2: Radio System Model

Equation (2) represents the amount of energy consumption in transmitting a packet with L bits over d distance according to the first order radio model. E_{elec} is the amount of energy utilized per bit to run the transmitter or receiver circuitry. E_{fs}, and E_{mp} is the amount of energy per bit dissipated in the RF amplifier according to the distance do which can be obtained from Equation (2)

$$E_{tx} = \begin{cases} L * E_{elec} + E_{fs} * L * d^2 & \text{, if } d<=do \\ L * E_{elec} + E_{fs} * L * d^4 & \text{,if } d>=do \end{cases} \quad (2)$$

Threshold distance is determined from the below equation:

$$d_o = \sqrt{E_{fs}}/E_{mp}$$

Amount of energy utilized for receiving a packet with L bits is calculated from the following equation:

$$E_{rx} = L * E_{elec}$$

3. PROPOSED METHOD

In our proposed method it has been identified that cluster head selection is done on the basis of using fuzzy if-then rules. Fuzzy theory provides a framework to materialize a fuzzy rule base system which contains the selection of fuzzy rules, membership functions, and its outcome surface diagrams. Fuzzy inference system consists of a fuzzification interface, a rule base, a database, a decision-making unit, and finally a defuzzification interface. The most important part of the proposed method is Fuzzy Inference System (FIS) [5]. The FIS has four parts and the architecture model is shown in Figure 3.

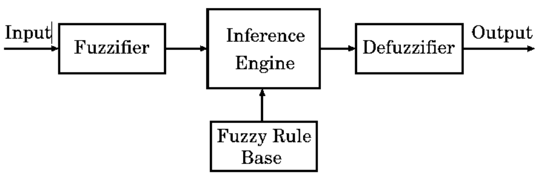

Fig 3: Fuzzy Logic System

In this method the most commonly used fuzzy inference technique is called Mamdani method due to its simplicity. The process is performed in four steps [4]:

1) Fuzzification – In this input is taking into the crisp value and convert these crisp values into fuzzy values, these conversion is based on the membership range.

2) Rule evaluation – In this input is taking into fuzzy form and applied to the antecedents of the fuzzy rules after that it's applied to the consequent membership function.

3) Aggregation of the rule outturns - the process of unification of the outturns of all rules.

4) Defuzzification - the input for the defuzzification process is the aggregate outturn of fuzzy set and the outturn is a single crisp number.

To balance the entire nodes energy consumption, designed algorithm constructs clusters at each round similar to LEACH. In the centralized algorithm, base station has the global view of the overall networks. Fuzzy logic is chosen to elect the suitable cluster head. The base station is more powerful than the sensor nodes in term of computation power, sufficient memory, unlimited power and storage. Gupta proved that, by considering three fuzzy parameters which are residual energy, concentration and centrality, the network lifetime can be improved [7].To get a cluster head election chance, three fuzzy sets and different fuzzy production rules for knowledge representation are considered. The fuzzy variables that are used in the fuzzy production rules are defined as follows [4].

1. Residual Energy – the energy remain of each node. The more residual energy used by a sensor node has definitely processed and transmitted the more data for a longer time.

2. Number of Neighbors – The number of neighbors are playing an important role during the selection of cluster head. It is more reasonable to select a cluster head in a region where the node has more neighbors.

3. Centrality – It represents how central the node is to the cluster. The more central the node is to a cluster head, the more is the energy efficiency for it to transmit the data through that cluster head.

In our proposed method evaluation of the cluster formation is done on the basis of following three fuzzy membership functions [7]:

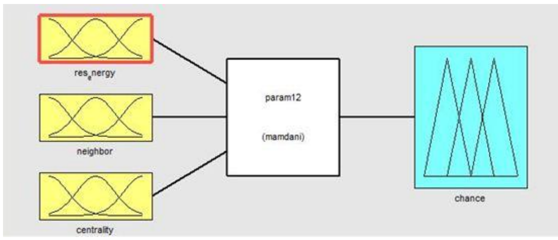

Fig 4: Fuzzy Inference System

The outcome of "residual energy" has three fuzzy sets high, medium and low and its membership function is shown in Figure 5

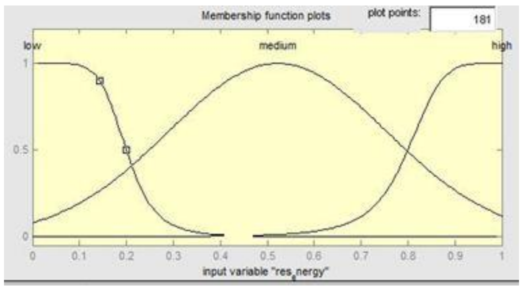

Fig 5: Membership Function of Residual Energy

The outcome of "neighbor" has three fuzzy sets – many, medium and few. The membership function is shown in Figure 6

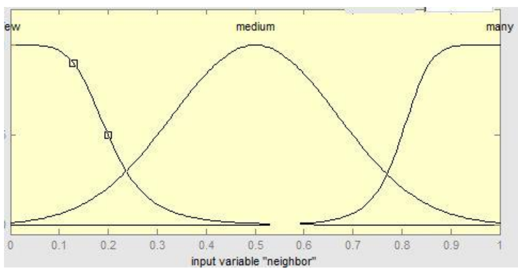

Fig 6: Membership function of neighbor

The outcome of "centrality" has three fuzzy sets far, medium and close, and its membership function is shown in Figure 7.

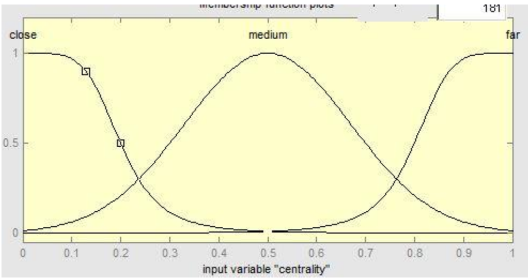

Fig 7: Membership function of centrality

The out-turn to show the node's cluster head election chance has five fuzzy sets –smallest, small, medium, large, and largest and its membership function is shown in Figure 8.

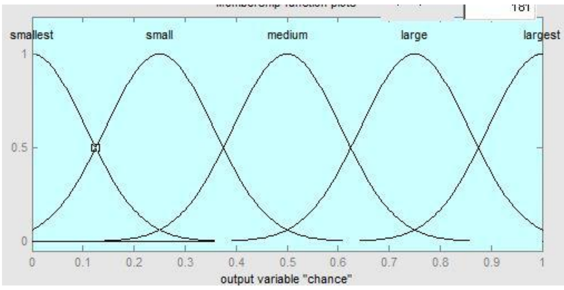

Fig 8: Membership function of chance

Since each input variable contains 3 linguistic states, so the total number of possible fuzzy inference rules is 3 × 3 × 3 = 27.

Table1: Fuzzy Rules

.RULE NO.	RESIDUAL ENERGY	NEIGHBOR	CENTRALITY	CHANCE
1	LOW	FEW	CLOSE	SMALL
2	LOW	FEW	MEDIUM	SMALL
3	LOW	FEW	FAR	SMALLEST
4	LOW	MEDIUM	CLOSE	SMALL
5	LOW	MEDIUM	MEDIUM	SMALL
6	LOW	MEDIUM	FAR	SMALLEST
7	LOW	MANY	CLOSE	MEDIUM
8	LOW	MANY	MEDIUM	SMALL
9	LOW	MANY	FAR	SMALLEST
10	MEDIUM	FEW	CLOSE	MEDIUM
11	MEDIUM	FEW	MEDIUM	SMALL
12	MEDIUM	FEW	FAR	SMALLEST
13	MEDIUM	MEDIUM	CLOSE	LARGE
14	MEDIUM	MEDIUM	MEDIUM	LARGEST
15	MEDIUM	MEDIUM	FAR	SMALL
16	MEDIUM	MANY	CLOSE	LARGE
17	MEDIUM	MANY	MEDIUM	LARGEST
18	MEDIUM	MANY	FAR	SMALL
19	HIGH	FEW	CLOSE	LARGEST
20	HIGH	FEW	MEDIUM	SMALL
21	HIGH	FEW	FAR	SMALLEST
22	HIGH	MEDIUM	CLOSE	LARGEST
23	HIGH	MEDIUM	MEDIUM	LARGE
24	HIGH	MEDIUM	FAR	LARGEST
25	HIGH	MANY	CLOSE	LARGEST
26	HIGH	MANY	MEDIUM	LARGE
27	HIGH	MANY	FAR	SMALL

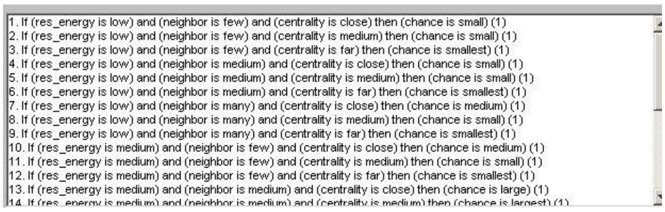
1. If (res_energy is low) and (neighbor is few) and (centrality is close) then (chance is small) (1)
2. If (res_energy is low) and (neighbor is few) and (centrality is medium) then (chance is small) (1)
3. If (res_energy is low) and (neighbor is few) and (centrality is far) then (chance is smallest) (1)
4. If (res_energy is low) and (neighbor is medium) and (centrality is close) then (chance is small) (1)
5. If (res_energy is low) and (neighbor is medium) and (centrality is medium) then (chance is small) (1)
6. If (res_energy is low) and (neighbor is medium) and (centrality is far) then (chance is smallest) (1)
7. If (res_energy is low) and (neighbor is many) and (centrality is close) then (chance is medium) (1)
8. If (res_energy is low) and (neighbor is many) and (centrality is medium) then (chance is small) (1)
9. If (res_energy is low) and (neighbor is many) and (centrality is far) then (chance is smallest) (1)
10. If (res_energy is medium) and (neighbor is few) and (centrality is close) then (chance is medium) (1)
11. If (res_energy is medium) and (neighbor is few) and (centrality is medium) then (chance is small) (1)
12. If (res_energy is medium) and (neighbor is few) and (centrality is far) then (chance is smallest) (1)
13. If (res_energy is medium) and (neighbor is medium) and (centrality is close) then (chance is large) (1)
14. If (res_energy is medium) and (neighbor is medium) and (centrality is medium) then (chance is largest) (1)

Fig 9: Fuzzy rules in MATLAB

1. If (residual energy is low) and (neighbor is few) and (centrality is close) then (chance is small).
2. If (residual energy is low) and (neighbor is few) and (centrality is medium) then (chance is small).
3. If (residual energy is low) and (neighbor is few) and (centrality is far) then (chance is smallest).
4. If (residual energy is low) and (neighbor is medium) and (centrality is close) then (chance is small).
5. If (residual energy is low) and (neighbor is medium) and (centrality is medium) then (chance is small).
6. If (residual energy is low) and (neighbor is medium) and (centrality is far) then (chance is smallest).
7. If (residual energy is low) and (neighbor is many) and (centrality is close) then (chance is medium).
8. If (residual energy is low) and (neighbor is many) and (centrality is medium) then (chance is small).
9. If (residual energy is low) and (neighbor is many) and (centrality is far) then (chance is smallest).
10. If (residual energy is medium) and (neighbor is few) and (centrality is close) then (chance is medium).
11. If (residual energy is medium) and (neighbor is few) and (centrality is medium) then (chance is small).
12. If (residual energy is medium) and (neighbor is few) and (centrality is far) then (chance is smallest).

13. If (residual energy is medium) and (neighbor is medium) and (centrality is close) then (chance is large).
14. If (residual energy is medium) and (neighbor is medium) and (centrality is medium) then (chance is largest).
15. If (residual energy is medium) and (neighbor is medium) and (centrality is far) then (chance is small).
16. If (residual energy is medium) and (neighbor is many) and (centrality is close) then (chance is large).
17. If (residual energy is medium) and (neighbor is many) and centrality is medium) then (chance is largest).
18. If (residual energy is medium) and (neighbor is many) and (centrality is far) then (chance is small).
19. If (residual energy is high) and (neighbor is few) and (centrality is close) then (chance is largest).
20. If (residual energy is high) and (neighbor is few) and (centrality is medium) then (chance is small).
21. If (residual energy is high) and (neighbor is few) and (centrality is far) then (chance is smallest).
22. If (residual energy is high) and (neighbor is medium) and (centrality is close) then (chance is largest).
23. If (residual energy is high) and (neighbor is medium) and (centrality is medium) then (chance is large).
24. If (residual energy is high) and (neighbor is medium) and (centrality is far) then (chance is largest).
25. If (residual energy is high) and (neighbor is many) and (centrality is close) then (chance is largest).
26. If (residual energy is high) and (neighbor is many) and (centrality is medium) then (chance is large).
27. If (residual energy is high) and (neighbor is many) and (centrality is far) then (chance is small).

From the fuzzy designed nets model, each node can get the fuzzy variable *chance*. The node with highest chance could be considered as a cluster head.

4. SIMULATION AND RESULT

Fuzzy rule based system is a non linear mapping technique of representing input data into outturn. The proposed fuzzy logic based cluster head election algorithm takes three input fuzzy variables Residual Energy, Neighbor and Centrality. The absolute value of each of these parameters can take a large range at different points on the network. Range for each membership function is taken between 0-1.

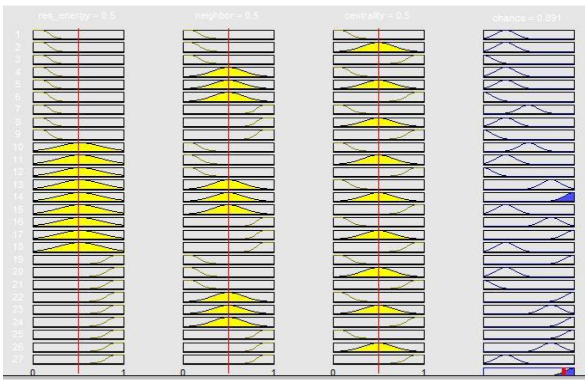

Fig 10: Rule Viewer

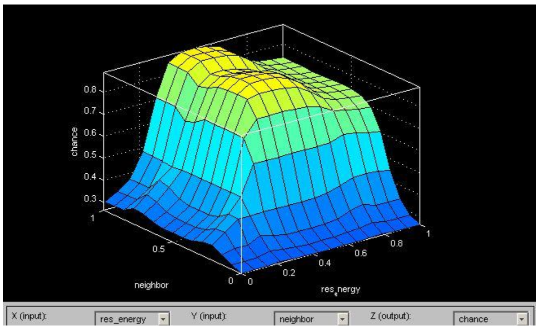

Fig 11: Chance with respect to neighbor and residual energy

In the figure 11, the 3 D decision surface illustrate the outturn variable cluster head election chance with respect to the input variable named neighbor and another input variable named residual energy.

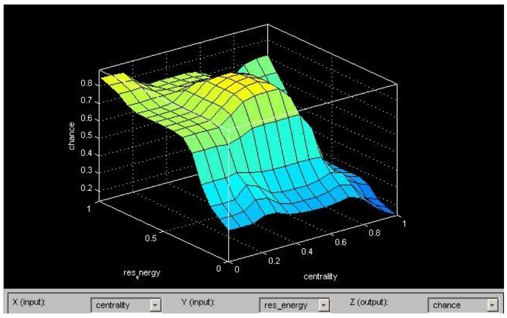

Fig 12: Chance with respect to residual energy and centrality

In the figure 12 , the 3 D decision surface illustrate the outturn variable cluster head election chance with respect to the input variable named residual energy and another input variable named centrality.

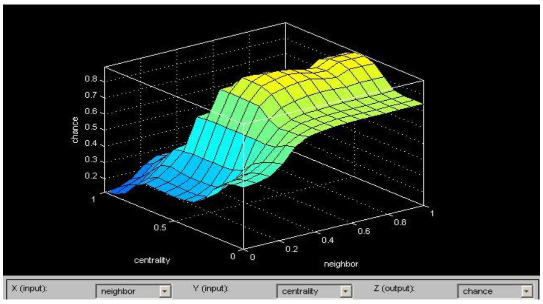

Fig 13: Chance with respect to centrality and neighbor

In the figure 13 , the 3 D decision surface illustrate the outturn variable cluster head election chance with respect to the input variable named centrality and another input variable named neighbor.

The simulation results indicate that when node residual energy is high and neighbor is few and node centrality is close the cluster head election chance is largest. But when node remaining energy is low and neighbor is many and node centrality is far then as a result the status of the cluster head election chance is small. Also when node residual energy is medium and neighbor is medium and centrality is medium then cluster head lection chance is largest. At last simulation results indicates that this method increased the overhead but in some other conditions our proposed algorithm works well.

5. CONCLUSION

In this paper cluster head selection is done by using fuzzy logic system for wireless sensor networks. In LEACH, cluster head is selected on the basis of probability. In this paper some limitations of LEACH protocol had been reduced by applying various conditions which would provide a more accurate outcome. Three fuzzy descriptors are used that is node residual energy, node's neighbor and it's centrality for selecting the cluster head on the basis of chance value. We will identify using fuzzy descriptors that which node is having more chance to become a cluster head and also helps in increasing the lifetime of sensor nodes.

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