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Fuzzy Logic Based Cluster Routing Techniques in WSN

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ABSTRACT

Wireless Sensor Network (WSN) organized network made up of a large number of sensor nodes that are limited in energy source, computation capability and storage capacity. Major issue in WSN networks is energy efficiency. Clustering provides an efficient way for extending the wireless sensor network life. Appropriate cluster-head node selection can effectively decrease the energy consumption and prolong the entire network lifetime. In this paper, improved clustering algorithms are evaluated based on fuzzy logic which takes energy level, distance from cluster head and crowdedness, consistent throughput to the Base Station (BS), based on fuzzy logic

Keywords: Cluster-Head, Fuzzy Logic, Routing Protocol, Wireless Sensor Network

1. INTRODUCTION

Wireless Sensor Networks are absolutely reliant on specific application and are constrained by energy, storage capacity, and power. For each routing protocol, knowledge is essential consideration to prolong life span of the network. Routing protocols are dependable for judgment and maintaining the routes in the network [1]. Various applications are environment monitoring (e.g., traffic, security), manufacturing sensing and diagnostics (e.g., supply chain appliances, factory), infrastructure protection (e.g., power grids, water distribution), battle field knowledge (e.g., tracking, multistage), context-aware computing (e.g., intelligent name, environment). Clustering provides an well-organized way to keep the energy of the sensor nodes. Merely some nodes, called Cluster Heads are accountable to correspond with the base station for falling energy consumption. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol uses probabilistic replica for cluster head choice and rotates the cluster heads from time to time in order to balance energy consumption.

In this paper, section II gives an outline of related work. Section III describes proposed methodology based on different methods of fuzzy logic. Section IV gives Simulation results and comparison with LEACH and CHEF LEACH-R protocols [2]and LEACH with improved Leach With dividing the cluster into sub clusters[3]. Section V finally gives conclusion.

2. RELATED WORK

Wireless Sensor Network (WSN) is composed of small, minute disposable, little cost and low power burning up devices called sensors which are deployed in a monitored area. These sensors capture measurements related to the monitored physical parameters such as temperature, humidity. Cluster Head collects the sensed data from sensor nodes in and aggregates it, and sends it to the powerful Base Station. The Base Station stores and processes the data according to an application. (LEACH) Low Energy Adaptive

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Clustering Hierarchy is a characteristic hierarchical clustering routing protocol which sporadically selects the Cluster Heads randomly from all nodes in the WSN region [4].LEACH [5] is one of the clustering protocols that divide the energy congregation in the same sensor node by rotating the Cluster Head (CH).The elected CH in LEACH protocol is probability based model, therefore it can be observed that its disadvantages are mostly due to the consideration of local information [6]-[7]. Having the network overview to select suitable CH based on the critical parameters can develop the network lifetime. In [8], LEACH-ERE approach has been proposed, which is based on fuzzy-logic clustering approach and is an extension to the energy predication. Here, Cluster head selection is completed on the beginning of left over energy and the lifetime of the network is enhanced by evenly distributing the workload all the way through the network. In [9], power decline algorithm named F3N, is introduced for sensor networks which is based on Fuzzy logic and the number of fellow citizen nodes. In [10], LEACH protocol is modified using Fuzzy Logic, which takes distance, battery level and node density into consideration. It concludes that, battery level play a major role in the selection of Cluster head. In [11], Cluster-Heads are chosen on the basis of three fuzzy descriptors- energy, absorption and centrality. This approach additional improves the existence of network but is suitable for electing Cluster Heads for medium size clusters only. In [12], the role of sub-clusters structure and sub-cluster algorithm performance indicators in wireless sensor network is being discussed .Also the pros and cons of LEACH algorithm are described. In [13], Cluster head selection is done on the basis of local distance and energy. Fuzzy logic is used for reducing the collection and calculation overheads and finally the lifetime of the Sensor Networks is also being prolonged.

Also, in existing protocols the performance of network varies with the position of base-station i.e., at certain points the performance degrades very much, which is not good, as the position of base station is supposed to be changed every time, so we need a protocol which performs effectively well and is independent of the position of base station.

3. PROPOSED METHODOLOGY

LEACH operates in turns; each turn consists of two intermediate steps which are the steady phase and set-up phase.The set-up phase has cluster set-up phase and advertisement phase while the steady phase conatins the data transmission. And schedule creation. During each round, the node independently generates a random numbers between 0 and 1.

When the generated number is smaller than the threshold value T(n) which is explained by Equation (1), the node will be elected as CH for the current round. In this the sensor node is elected to be a CH, it will broadcast a message to its surroundings to notify the other sensor nodes as it had been elected as CH. Non-CH sensor nodes might get lesser message from various CHs and they will elect to join the closest CH based on the RSS. After some time, CH will again broadcast the (TDMA) time division medium access to its cluster and the cluster members will transmit their sensed data to the CH according to the predefined time slot shown in TDMA.

$$T(n) = \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)} \text{ if } n < G \tag{1}$$

The description of every symbol is r, is the round which already ended, p is the proportion of the nodes to CHs and G is set of nodes which have never been CH in the last $1/p$ rounds.

Although the nature of LEACH protocol can distribute the heavy workload by revolving the CH, but the protocol faces some of the disadvantages as shown below:

- Elected CH may place near to each other which results in uneven cluster formation.
- The number of elected CHs is not consistent in each round hence the BS will get more or no data during each round.

The elected CH may appear at the edge of the network and undesirable location.

The proposed work uses Fuzzy logic System. In this paper, we are considering two scenarios based on Fuzzy logic. For the Ist scenario[2], improved Leach Routing protocol is proposed based on the Fuzzy logic, for appropriate Cluster Head selection and it prolongs the lifetime of Wireless Sensor Network. The Fuzzy Inference System consists of four basic elements are shown in figure 1 below.

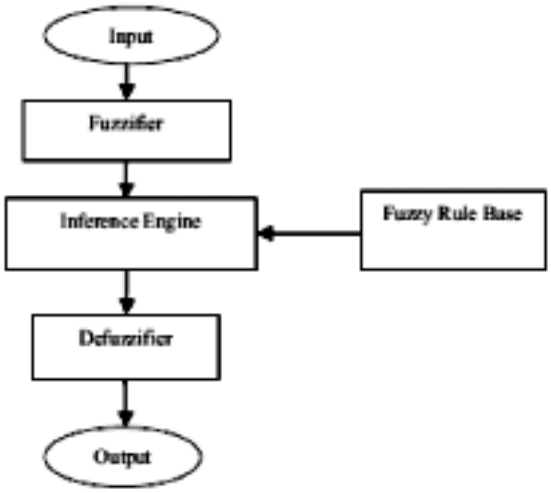

Figure 1: Fuzzy Inference System

The essentials are Fuzzifier, Inference engine, Fuzzy rule base (FRB) and Defuzzifier.

Fuzzification : converts the system inputs, that is crisp numbers, into fuzzy sets. This is completed by applying a fuzzification task.

Fuzzy rule: provisions IF-THEN rules.

Inference engine the inputs and IF-THEN rules are simulated by the human being interpretation process by creating fuzzy inference.

Defuzzification: a crisp value can be obtained by transforming the fuzzy set obtained by the inference engine into Mamdani‘s method .and the inference process of the proposed method is used by this.

Triangular membership functions are used in projected method as given away in diagram in fig.2.

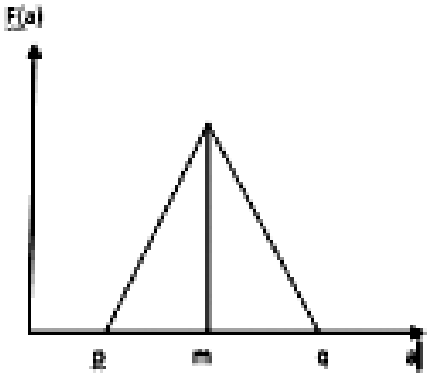

Figure 2: Triangular function membership

Triangular task is defined by a lower bound ‘a’, and upper bound ‘b’ and a value ‘m’ where, a<m<b key variables and their membership task are shown in Table 1

Table 1
Input Variables And Their Membership Function

Input Variable	*Membership Function*
Distance from cluster heads	Low, Medium, High, Very High
Battery Level	Very low, Low, Little Low Medium, Medium, Lower strong, Strong, Very Strong
Crowded ness	Low, Medium, High, Very High

The production variables and their membership task is shown in Table 2.

Table 2
Output Variables and their Membership Fucntion

Output	Membership Function
chance	Very low, Low, Little Low, Medium, Medium, Medium, Lower Strong, Strong, Higher Strong

Rule Evaluation

Rules are developed based on the fuzzy sets of nodes, Battery Level, Crowdedness, and Distance from Cluster Head are:

Level is very low AND Crowdedness is Very High AND

1. If Battery Level is very low AND Crowdedness is Very High AND Distance from Cluster Head is Very High THEN output is Very Low.
2. If Battery Level is very low AND Crowdedness High AND Distance from Cluster Head is output is Very Low.
3. If Battery Distance from Cluster Head is Medium THEN output is Very Low.

And so on

Algorithm for leach-R based on fuzzy logic

Step 1. Start

Step 2. Elect Head Node, Clustering

Step 3. Run the Fuzzy logic Algorithm

Step 4. Calculate Distance from Cluster Head, Battery Level, Crowdedness

Step 5. If size of Cluster > α If yes then Split the cluster into sub-clusters, after that go to step 2.
Step 6. If chance > Threshold if no then step 8
Step 7. Select that Node as Cluster Head
Step 8. Data collection from cluster-node is done by cluster head.
Step 9. Cluster Head Transmit the data to the Base station
Step 10. End

In the 2nd scenario LEACH method pros and cons in using either energy or distance as the factor to elect the CH. By Using fuzzy logic to consider both factors will develop the CH selection process. The finest output can be obtained based on the fuzzy rule base system. Fuzzy inference skill via Mamdani method is used due to its simple structure. In Mamdani technique, there are four important steps as shown below fig. 3.

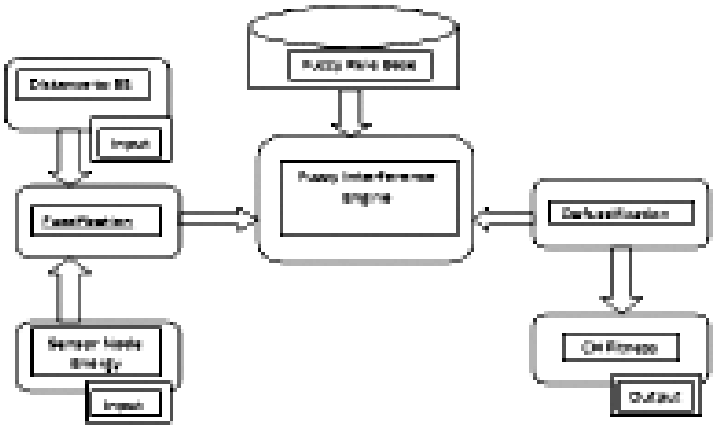

Figure 3: shows the block diagram of the fuzzy logic control used in this work.

Sensor node residual energy and separate distance between BS and CH are the fuzzy inputs that go through fuzzification procedure. Fuzzy inference engine will modify the inputs from fuzzification based on the rules that set in the fuzzy method.Finally, in the defuzzification module, the fuzzy set obtained from inference engine needs to be transformed into the single crisp value. The common Centre Of Area (COA) is used to compute the crisp value using Eq. (2) where μA(*x*) refers to the membership function of the fuzzy sets:

$$\text{Fitness} = \left(\int x.\, \mu_A(x)\; dx \,/ \int x\; dx \right) \tag{2}$$

3. PERFORMANCE E EVALUATION AND RESULT ANALYSIS

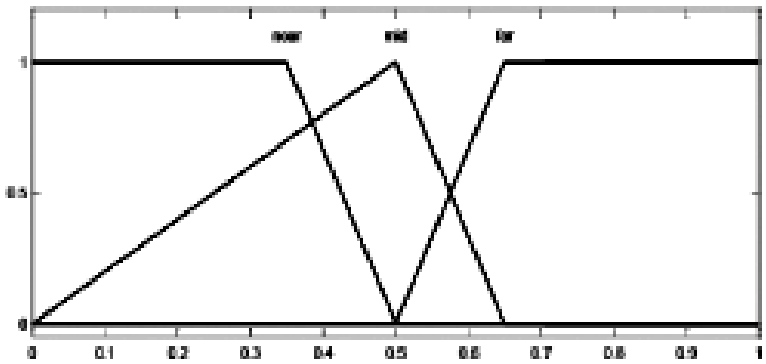

Figure 4: Membership functions of Node

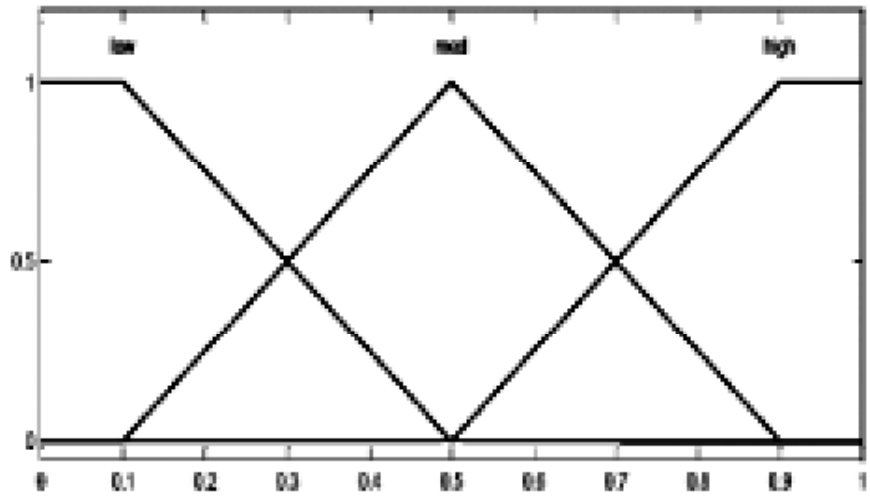

Figure 5: Membership function of Node energy

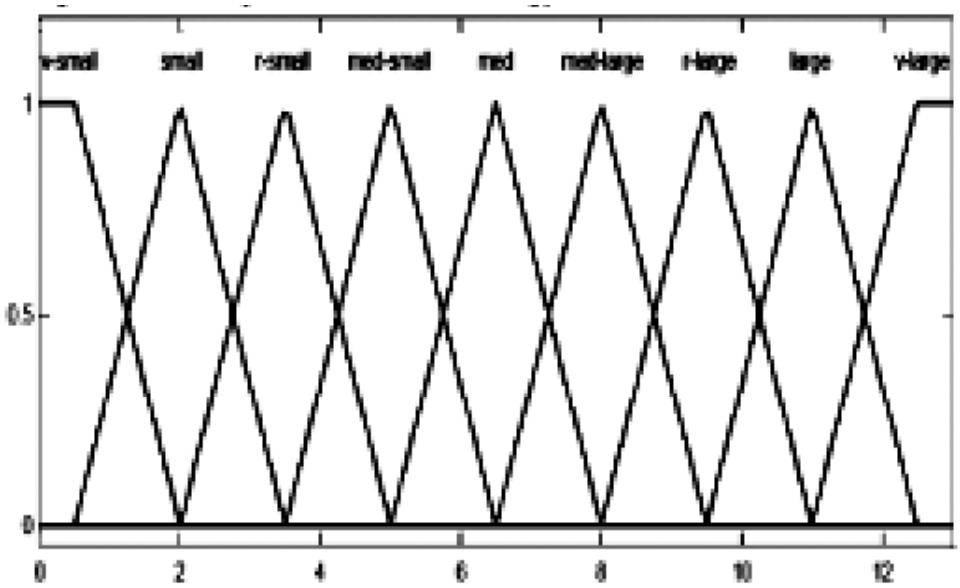

Figure 6: Membership functions of CH fitness

Table 3 shows the fuzzy rule base set in the fuzzy inference system (FIS). By referring to the distance's rule base, 'middle' is set to top priority than 'near' because the CH in the 'middle' zone will perform

Table 3
Fuzzy Rule Base

Sl. No.	*Energy*	*Distance*	*Fitness*
1	low	Far	very small
2	low	Near	small
3	low	Middle	rather small
4	medium	Far	medium small
5	medium	Near	medium
6	medium	Middle	medium large
7	high	Far	rather large
8	high	Near	large
9	high	Middle	very large

superior than the near‘ zone which has been explained in the section 3. The example of rule can be elaborated, if the remaining energy is ‘low’ and the separate distance is ‘far’ then the strength to be chosen as CH will be very ‘small’. Conversely, if the residual energy is ‘high’ and the separate distance is ‘middle’, the power is considered very much more.

In this section, for Ist and IInd scenario, simulations are performed in MATLAB under the simulation parameter which has been given in Table 4 and Table 5 and compared proposed clustering algorithm LEACH-R with two different algorithms, namely LEACH and CHEF protocols and LEACH with proposed fuzzy algorithm.Fig.7 and Fig.8 clearly shows the Graphical comparison of network life span at Base station (50,175) and (50,150) for both the scenarios respectively.

Table 4
Simulation Parameter

Parameter	*Value*
Topology Size	30 × 100 m2
BS position	15 m,150m
Simulation round	200
No of nodes	70

Table 5
Simulation Parameter

Parameter	*Value*
Topology	100 × 100 sq
Size	unit
BS position	50,175
Simulation round	500
No of nodes	100

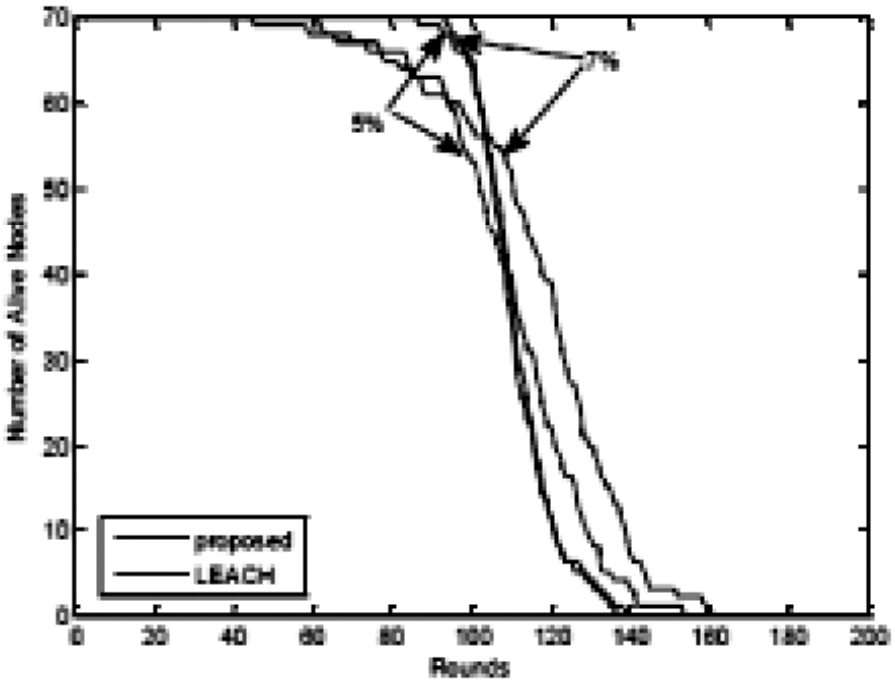

Figure 7: Graphical Comparison of Network lifetime at base station is locatedat point (50, 175).

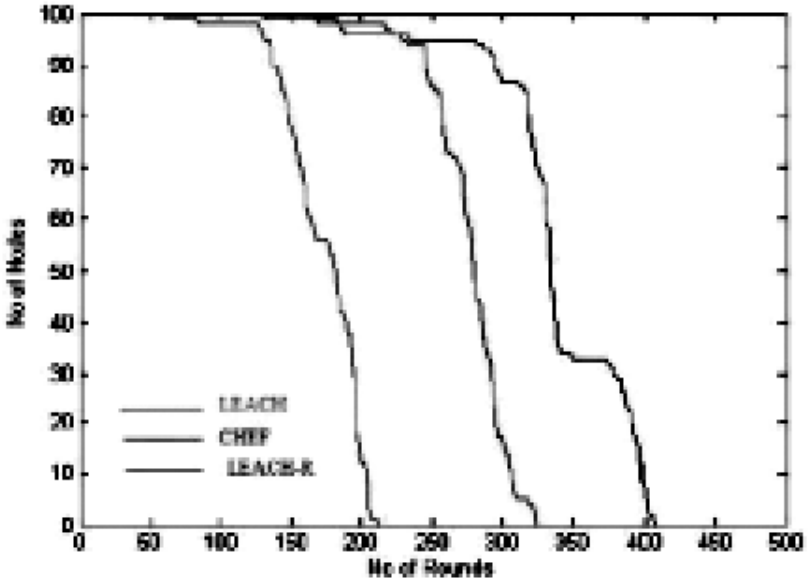

Figure 8: Graphical Comparison of Network lifetime at base station is located at point (50, 175).

4. CONCLUSION

The most famous clustering mechanism used for Cluster Head selection in LEACH protocol is based on probability model. But this model, suffers from one of the major flaws that is inappropriate Cluster Heads selection which results in high energy consumption thereby reducing the nodes life time. The paper uses Fuzzy logic based approach for Cluster Head selection. In the proposed algorithms, the clustering is done based upon the comparison that if the size of cluster is greater than a certain pre-defined value i.e. threshold value, then the cluster is divided into sub-clusters, after clustering, cluster head selection is done based upon the fuzzy logic approach. On comparing the results obtained from the proposed approach with LEACH and CHEF approaches, we find that the results shows an enhanced performance, thereby maximizing the lifetime of the network and minimizing the energy consumption.

The improvisation over LEACH protocol using the decided fuzzy logic is when it used sensor node‘s remaining power as one of the factor to be counted in considering the CH. Therefore, the CH of fuzzy logic control will maintain the node energy by more appropriate CH selection. Using more number of CHs will eventually pave way to to more overhead and cause the sensor nodes sacrifice faster without providing consistent and continuous significant information. so, Fuzzy Logic based CH selection gives more significant result than the other approach. In future work, Single Source Shortest path algorithm or the ACO (Ant Colony Optimization) Algorithm can be used with the proposed methodology to find the optimal route between Cluster Heads and Base Station.

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