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WSN Protocol based on LEACH Protocol using Fuzzy

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Abstract

A wireless sensor network is a network in which nodes equipped with sensors capable of collecting data from the real world are configured wirelessly. Because the sensor nodes are configured wirelessly, they have limited power such as batteries. If the battery of the sensor node is exhausted, the node is no longer usable. If more than a certain number of nodes die, the network will not function. There are many wireless sensor network protocols to improve energy efficiency, among which LEACH Protocol is a typical example. The LEACH protocol is a cluster-based protocol that divides sensor space into clusters and transmits and receives data between nodes. Therefore, depending on how the cluster is structured, the shape of the energy cow may decrease or increase. We compare the network lifetimes of the existing LEACH protocols and the three types of protocols that have been improved using fuzzy methods for cluster selection.

Keywords: Wireless, Sensor, Network, Protocol, Fuzzy.

INTRODUCTION

A wireless sensor network is a network in which sensor nodes collecting data are composed wirelessly. Sensor nodes can be installed in a home, a natural environment, or on the road to measure or observe changes. In addition, since the sensor nodes are wirelessly configured, they can be installed where people cannot access. These networks are used in many field and make our lives more convenient. Wireless sensor networks have these advantages, but they also have disadvantages. Unlike a wired network, a wireless sensor network operates with a limited power source such as a battery for each sensor node. When the battery is exhausted, the sensor node no longer functions. So, for a network to be used for a long time, it needs to optimize the energy consumed to minimize energy consumption. There are many wireless sensor network protocols to increase the energy efficiency of the network [1][2][3], One of the typical protocols is the LEACH Protocol [4]. The LEACH Protocol is a cluster-based protocol that cyclically selects the cluster head using the cluster head election probability equation. However, the LEACH Protocol does not take into consideration the residual energy of the node or the distance between the nodes, so that the cluster may be formed inefficiently.

To improve this, protocol applying Fuzzy Logic is proposed. and Gupta's Fuzzy Logic and CHEF, LEACH-FL of among them are compared with the LEACH protocol.

BODY

LEACH Protocol

The LEACH Protocol is a cluster-based routing protocol. The sensor field is divided into clusters, and each cluster has one node that is responsible for the cluster head. The LEACH protocol has a set-up phase in which cluster heads are selected and a steady-state phase in which data of nodes is transmitted. Since cluster head collects the data of the member nodes in the cluster and transmits the data, energy consumption of cluster head is high. For uniformly distributing energy consumption, the LEACH Protocol changes the cluster every cycle.

$$T(n) = \begin{cases} \dfrac{p}{1 - p(r \bmod \frac{1}{p})} & if \quad n \in G \\ 0 & otherwise \end{cases} \qquad (2.1)$$

In the above equation (2.1), r represents the current round. The set G is a set of nodes not selected in the cluster head until the previous round. If the set G is empty and there are no nodes that can be cluster heads, we put all nodes remaining energy into the set G to it becomes the cluster head. When each round begins, each node independently checks whether it belongs to the set G, and if it belongs to the set G, it compares random number between 0 and 1 of itself with the stochastic threshold. If the random number is less than the threshold $T(n)$, the node becomes the cluster head in the current round. Once all the cluster heads are selected, the member nodes in the cluster transmit the data to the cluster head. The cluster head collects the received data and transmits it with its own data to the base station.

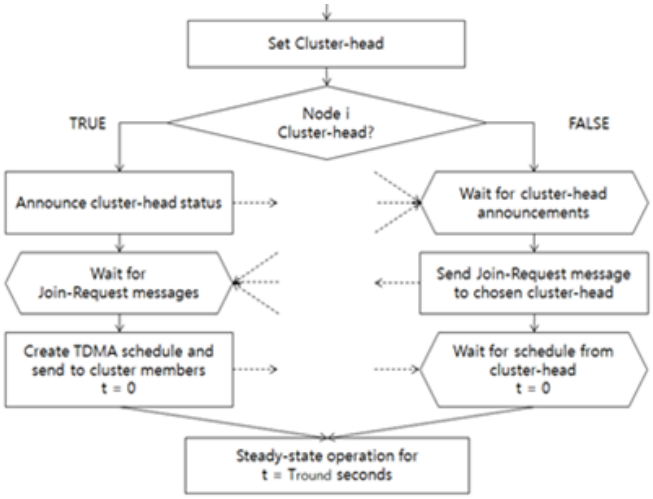


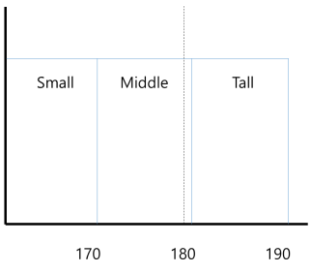
Figure 1. Flowchart of LEACH Protocol

Fuzzy Logic

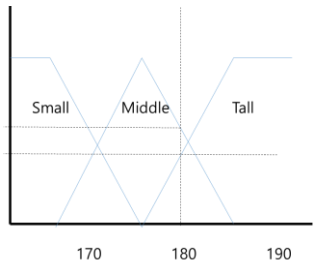
Fuzzy Logic is a logic concept that expresses elements or ambiguous states that can occur in natural language, etc., as ambiguous states rather than binary logic.

The fuzzy logic is basically based on the concept of the fuzzy set proposed by Lotfi Asker Zadeh in 1965, and expresses that the comparison object belongs to the set A by one quantity using the Membership Function rather than the true binary logic.

Figure 2 shows the set of human height using binary logic and fuzzy logic.



(a) Binary logic



(b) Fuzzy logic

Figure 2. Range of height in binary logic and fuzzy logic

When a person with a height of 179.9 cm is judged by binary logic, the comparison object belongs to the 'Middle' set because it is less than 180 cm and therefore does not belong to the 'Tall' set.

However, when judged by the fuzzy logic, a person with 179.9cm can be expressed as a mathematical function that belongs to a set of 'Middle' and 'Tall'.

Gupta's Fuzzy Logic

Gupta [5] tried to improve the cluster head selection criterion of the LEACH Protocol through Fuzzy logic. The cluster head is selected by the fuzzy operation considering the residual energy of the node, the density of the node, and the centrality of the node instead of the stochastic threshold. Fuzzy operation uses Mamdani inference method and goes through the following process.

1. Input variable fuzzification: input the residual energy of the node, the density of the node and the centrality of the node and Determine the degree to which each input belongs to the appropriate fuzzy set and convert it to a member function.
2. Fuzzy rule evaluation: Assign fuzzy input variables using fuzzy rule and infer result.
3. Output rules and aggregation: Consolidate and output inferred results.
4. Defuzzification: The process of converting the output fuzzy values to their normal values

Calculate using the center-of-gravity method in defuzzification. The equation is shown in Equation (2.2) below.

$$COG = (\sum \mu_A(x) * x) / \sum \mu_A(x) \quad (2.2)$$

Gupta's Fuzzy Logic has input variables and fuzzy set as shown in Table 1 and Figure 3.

Here, the node density refers to the node density within the range of 20M x 20M, 10M up, down, left and right based on the corresponding node.

Table 1. Input variable: Gupta's Fuzzy Logic

Input variable	*Set Value*		
Node Energy	low	med	High
Node Concentration	low	med	High
Node Centrality	close	adeq	far

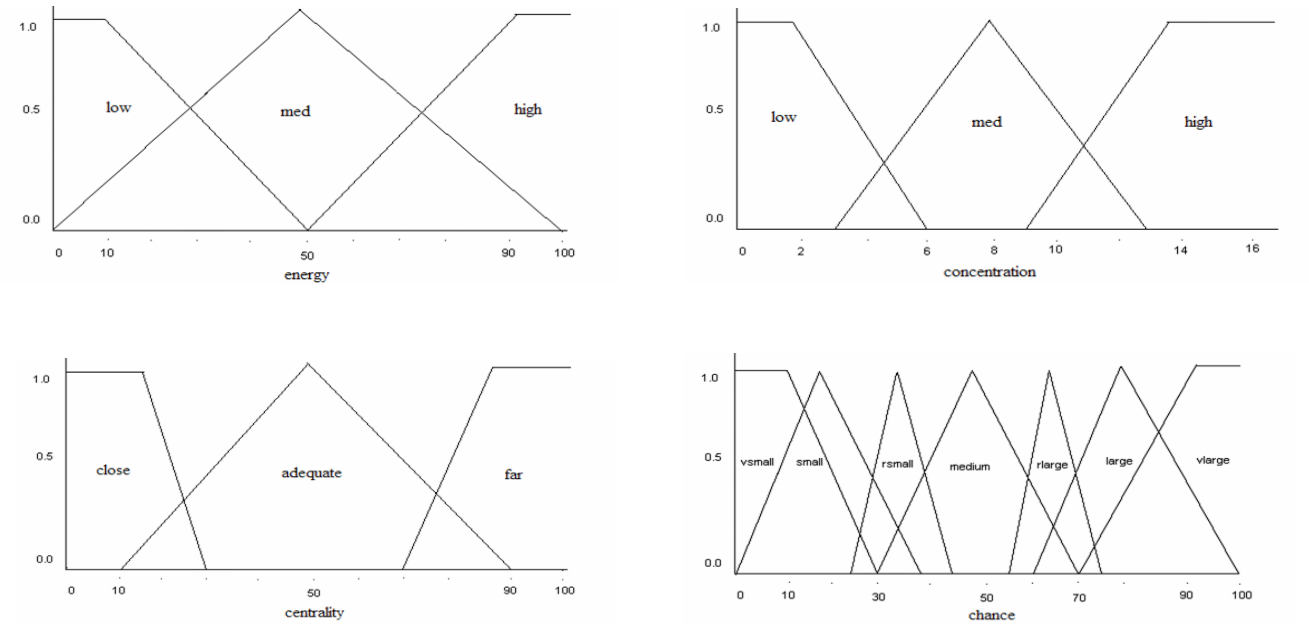


Figure 3. Fuzzy set of input variable: Gupta's Fuzzy Logic

In Gupta's Fuzzy Logic, the chance value of all nodes is calculated every round. When the chance value calculation is completed, the cluster heads are selected in ascending order of the chance value.

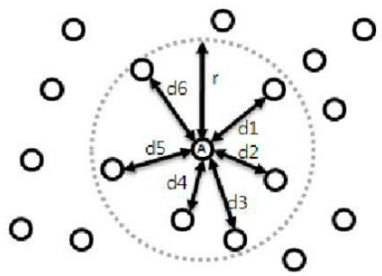
CHEF

Fuzzy Logic of CHEF has input variables and fuzzy sets as shown in Table 2 and figure 4.

The centrality of node the sum of the distances from nodes located within a certain range r of the node as shown in Figure 5. The range is given by Equation (2.3) bellow.

$$r = \sqrt{\frac{M}{\pi n P}} \qquad (2.3)$$

Where M is the size of the sensor space, P is the cluster head selection probability, and n is the total number of nodes.



Node Centrality = d1 + d2 + d3 + d4 + d5 + d6

Figure 4. Distances between the node A and other nodes within *r*

Table 2. Input variable: CHEF

Input variable	*Set Value*		
Node Energy	low	med	High
Node Centrality	close	adeq	far

In the case of CHEF, the cluster head is selected in the same way as the LEACH Protocol.

After electing cluster head, the cluster head is compared with opportunity value of its member node. And cluster head is replaced with a node with higher value.

LEACH-FL

Fuzzy Logic of LEACH-FL has input variables and fuzzy set as shown in Table 3 and figure 5. Obtain the fuzzy probability value by using the following fuzzy set and following equation.

*Probability value = (Node Energy) * 2 + (Node density) + (2 – Node Centrality)*

Table 3. Input variable: LEACH-FL

Input variable	*Set Value*		
Node Energy	Low (0)	Med (1)	High (2)
Node Concentration	Low (0)	Med (1)	High (2)
Node Centrality	Close (0)	Adeq (1)	Far (2)

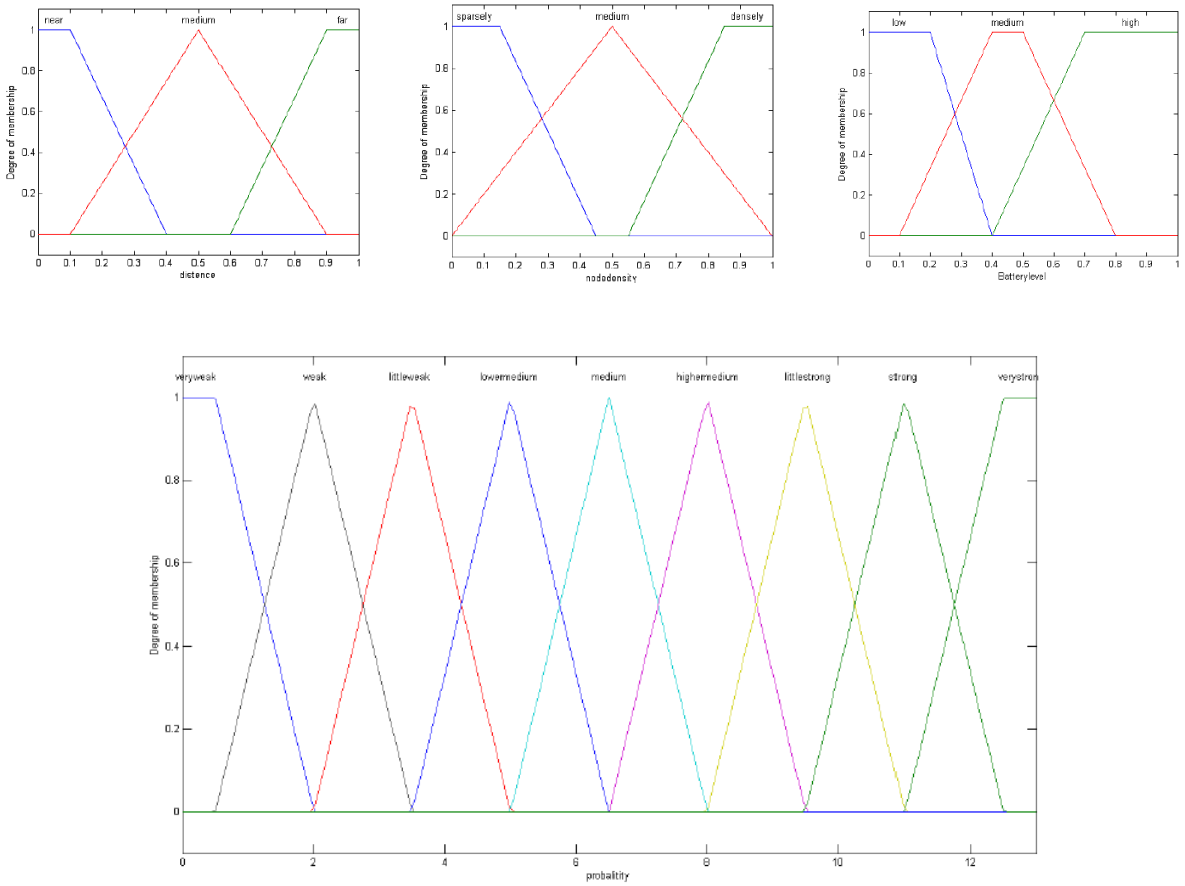


Figure 5. Fuzzy set of input variable: LEACH-FL

In the case of LEACH-FL, it operates almost the same as the LEACH Protocol.

LEACH Protocol select the cluster head by comparing stochastic threshold(T(n)) with random number of each node. But, LEACH-FL select the cluster head by comparing the calculated fuzzy probability value with T(n).

SIMULATION AND RESULTS

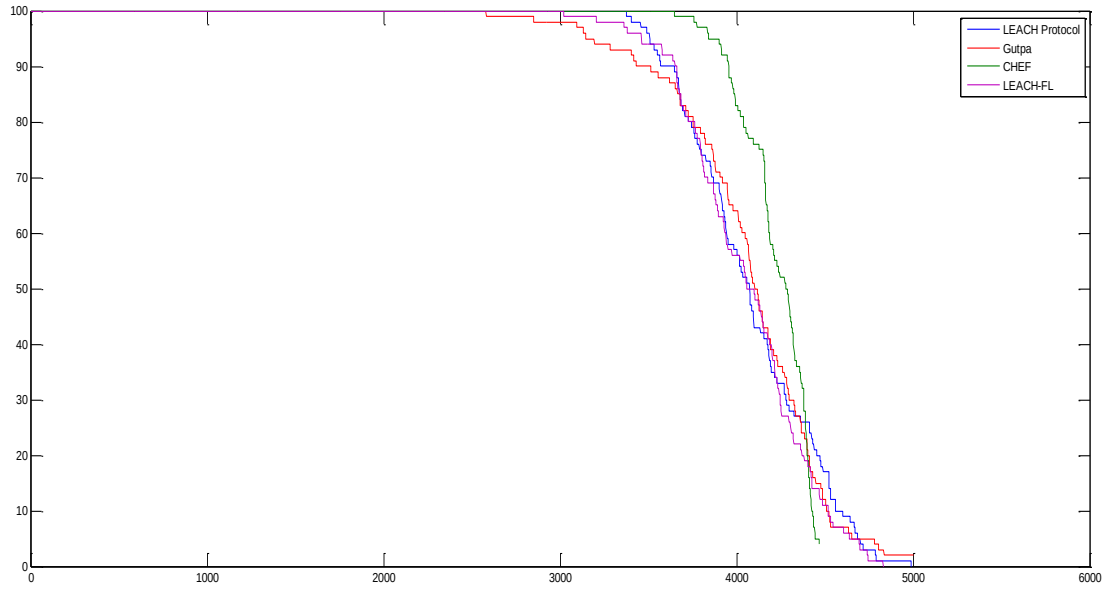
Simulation

We compared the network lifetime of LEACH Protocol with that of three protocols using Fuzzy Logic (Gupta's Fuzzy Logic, CHEF, LEACH-FL) by applying Table 4. The simulation was conducted under the condition that the position of the base station is located at the center of the sensor field.

Table 4. Simulation Parameters

Parameter	*Value*
Data Aggregation	5nJ/bit/signal
Energy dissipation to run the radio device	50nJ/bit
Free space model of Transmitter Amplifier	10pJ/bit/m2
Multi path model of Transmitter Amplifier	0.0013pJ/bit/m2
Number of Sensor Nodes	100
Sensor Field	100 x 100
Location of Base Station	50 x 50(center), 50 x 150(outside)
Initial Energy	0.5J

SIMULATION RESULTS



	LEACH Protocol	*Gupta*	*CHEF*	*LEACH-FL*
FND	3375	2581	**3648 [8%▲]**	3021
80% Alive	3744	3754	**4038 [7.9%▲]**	3764
50% Alive	4074	4102	**4280 [5.1%▲]**	4057

Figure 6. Simulation Results

When the base station is located at the center of the sensor field, CHEF showed the best efficiency.

CONCLUSIONS

The simulation results show that CHEF has a high network lifetime improvement rate among three protocols using Fuzzy Logic.

CHEF uses a LEACH protocol threshold equation T(n) differently from other protocols, so the cluster is also changed depending on the location of the base station. Others show that clusters aren't changed regardless of position of base station.

Because of this, when the position of base station is outside, both Gupta's Fuzzy Logic and LEACH-FL may be inefficient.

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