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Improving adaptive cluster head selection of teen protocol using fuzzy logic for WMSN

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Abstract In this paper, we proposed the clustering algorithm using fuzzy inference system for improving adaptability the cluster head selection of TEEN for the wireless multimedia sensor network. The stochastic selection method cannot guarantee available of cluster head. Furthermore, as the formation of clusters is not optimized, the network lifetime is impeded. To improve this problem, we propose the algorithm that gathers attributes of sensor node to evaluate probability to be cluster head.

Keywords WMSN (Wireless Multimedia Sensor Network) · BSN (Body Sensor Network) · TEEN · Fuzzy logic · Energy efficiency · Hierarchical Routing Protocol

1 Introduction

The Wireless Multimedia Sensor Network (WMSN), Body Sensor Network (BSN) and Internet of Things (IoT) is hot issue on the IT field recently. The WMSN, BSN and IoT is the one kind of ubiquitous network which explained by 'Every object can

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communicate and information processing without human command'. To date, the internet cannot be operated by person [5]. While the WMSN, BSN and IoT can make a rational decision by gathered data, it gives a help to human [1, 5]. Also, the WMSN, BSN and IoT is the sensor network system to communicate data like as nervous system.

Generally, the Wireless Multimedia Sensor Network (WMSN) is the network system using many sensor nodes to gather and process data [10]. These sensor nodes are small but also low priced to make more cost-effectively on the overall network [1]. This type of system is usually used in disaster monitoring, military purpose, ubiquitous home network and body sensor network. In case of body sensor network, it has many sensors which placed on human body. This sensor collects the body information of target- for example blood pressure, heart rate and electromyography. The collected information transmits to the medical team for monitoring and helping to predict the target health status [9].

The most of sensor node in WSN has a limit on power and processing capacity. Therefore the first consideration for building sensor network system is the energy consumption. The issue of energy consumption can solve to make an optimized routing protocol which is considered as the method for gathering or transmitting data [1, 5]. The Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is representative routing protocol of reactive type sensor network [7]. This protocol elects the cluster head using stochastic threshold and forms a cluster. After clustering, every cluster head gathers data from its member node and transmits to the Base Station. The TEEN decides save and transmit the sensed data using two thresholds called Hard threshold (Ht) and Soft threshold (St). These thresholds already broadcasted in the cluster formation process.

In this paper, we suggest a new clustering algorithm based on TEEN using fuzzy logic on the cluster head selection. It improves network stability and uniformity of energy [11]. The energy consumption effectiveness increases. This paper is organized as follows. Within Chapter 2, we briefly described the well-known LEACH and TEEN protocol, and it describes the motivation in Chapter 3. In Chapter 4 it was described with respect to the algorithm proposed in this paper, and the simulation results for the proposed FL-TEEM was described in Chapter 5. And it was the last of conclusion.

2 Related work

2.1 Classification of wireless sensor networks

The modes of sensor network can classified by data collection, transmission method and period [6].

- Proactive Network: This type of node provides data processing (sense, transmit, analyze) periodically. It usually used in periodical data monitoring is required.
- Reactive Network: These network senses data when drastic change of environment attribute.

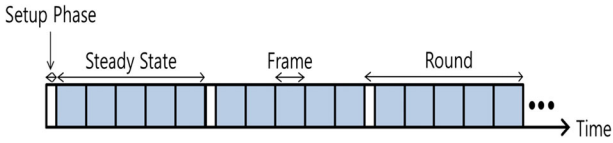


Fig. 1 Round configuration of LEACH

Therefore the reactive network suited for critical timing application and TEEN uses this network type.

Next, we will introduce briefly on the most common routing protocol [3, 7].

2.2 LEACH

LEACH is representative hierarchical routing protocol based on cluster [3]. This protocol splits whole network into several clusters and it has hierarchy structure which is consisted of the cluster head and its member node. The member node senses environmental value at regular interval and transmits sensed data to its cluster head. The cluster head processes the aggregation and compression for the received data before the data transmit to Base Station. LEACH has two process called 'Setup-Phase' and 'Steady-State'. In Setup-Phase, the protocol elects cluster head using Stochastic Threshold formula (1).

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

In this formula, P is probability of be the cluster head, T(n) is the threshold value of node n, r is the current round, G is the set of nodes that weren't cluster head the previous rounds. The elected cluster head by stochastic formula broadcasts the Advertise Message (ADV-msg) to the neighboring nodes. The normal node which weren't the cluster head receives this message and sends Join-Request message to its cluster head and forms a cluster. After cluster is formed, every cluster head makes TDMA schedule and allocates time slot to all the member node. In Steady-State,

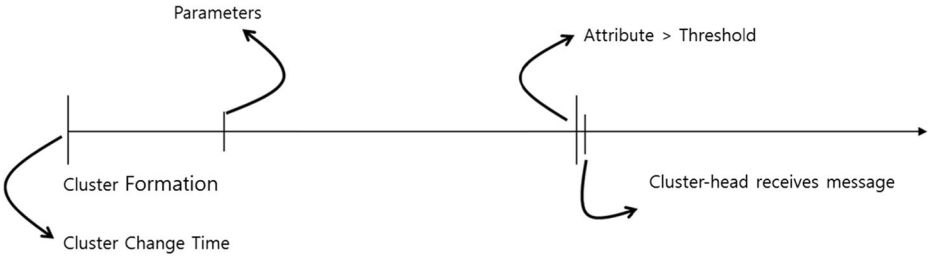


Fig. 2 Timeline of TEEN

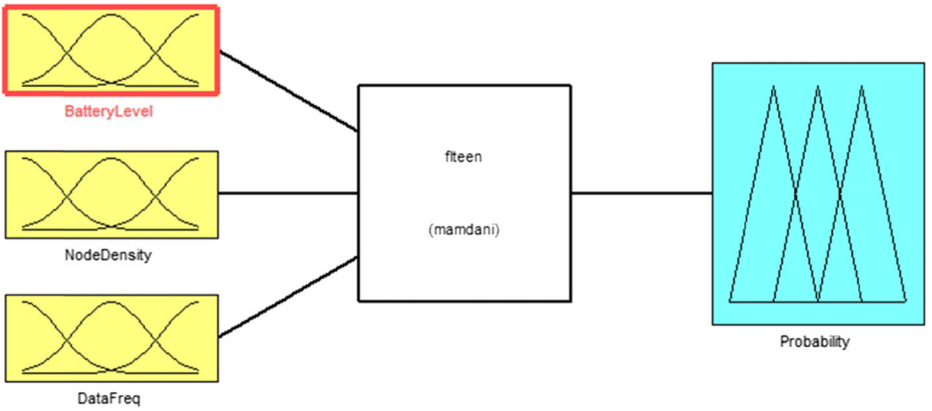


Fig. 3 Architecture of FL-TEEN

every Non-CH node wakes on its time slot for transmitting the sensed data. The cluster head gathers data from member nodes and data compresses and transmits to the Base Station. The combining the two processes (Setup-Phase and Steady-State) is referred to as 1 Round. Figure 1 shown round timeline of LEACH.

2.3 TEEN

TEEN (Threshold sensitive Energy Efficient sensor Network protocol) is the stochastic-hierarchical protocol in the same way as LEACH [7]. This protocol uses the same clustering algorithm of LEACH. However the sensor node does not transmits the sensed data periodically. To filter for data collection or transmission, the TEEN uses two threshold called the Ht(Hard threshold) and St(Soft threshold). These two thresholds broadcasted in clustering process. After this broadcast, the first data collection is begins. If the sensed data of sensor nodes are bigger than Ht, the entire node saves it. And it transmits the saved data at own time slot. Figure 2 shows the timeline of TEEN.

In clustering process, TEEN sets two thresholds for adjust the data collection flexibly. For this reason TEEN is suitable to observe drastic change like seismic monitoring system and fire detection system.

Table 1 Input & output function

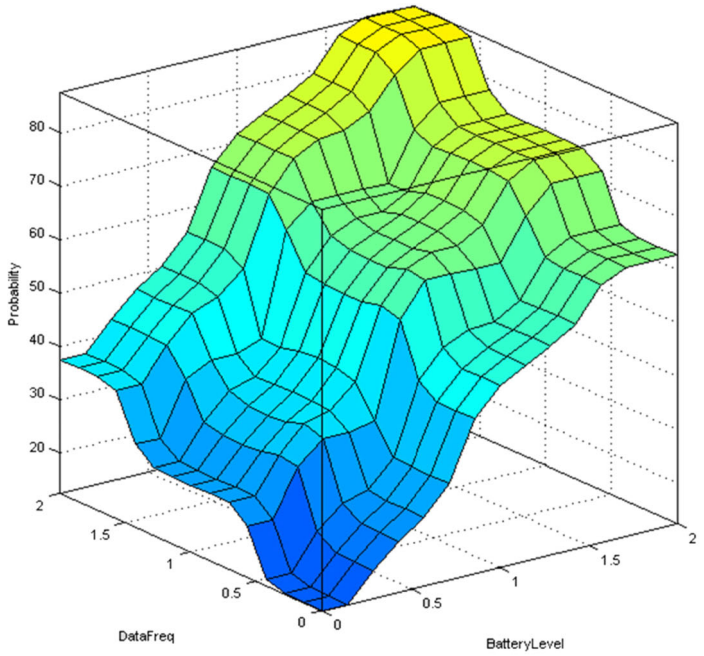
Input Function	
Battery level	Current residual energy
Node density	Number of neighbor available node
Data frequency	Data occurrence frequency
Output function	
CH_{prob}	Probability of be a cluster head

Table 2 Fuzzy rule table

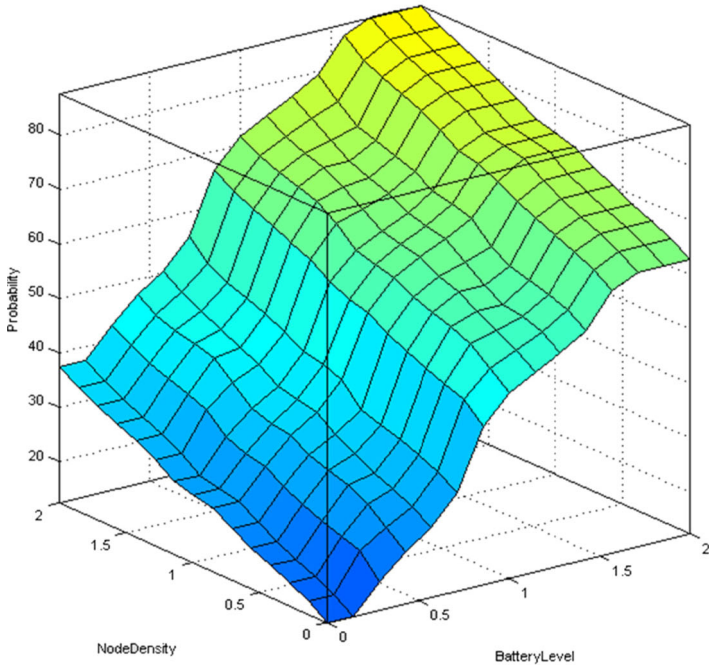
Battery level	Node density	Data frequency	CH_{prob}
Low	Low	Low	Lower low
Low	Low	Medium	Low
Low	Low	High	Higher low
Low	Medium	Low	Low
Low	Medium	Medium	Higher low
Low	Medium	High	Lower medium
Low	High	Low	Higher low
Low	High	Medium	Lower medium
Low	High	High	Medium
Medium	Low	Low	Higher low
Medium	Low	Medium	Lower medium
Medium	Low	High	Medium
Medium	Medium	Low	Lower medium
Medium	Medium	Medium	Medium
Medium	Medium	High	higher Medium
Medium	High	Low	Medium
Medium	High	Medium	Higher medium
Medium	High	High	Lower high
High	Low	Low	Medium
High	Low	Medium	Higher medium
High	Low	High	Lower high
High	Medium	Low	Higher medium
High	Medium	Medium	Lower high
High	Medium	High	High
High	High	Low	Lower high
High	High	Medium	High
High	High	High	Higher high

3 Motivation

TEEN changes the transmission method from periodically transmission to Event-Driven for increases in energy efficiency [7]. It can solve problem of low energy efficiency in data transmission. However, the TEEN and LEACH has some issues in cluster head selection process. This cluster head selection method using Stochastic threshold cannot guarantee the reliability of selected cluster head. To solve this problem, we adopt the Fuzzy Inference System in cluster head selection using residual energy, data collection frequency and position. The LEACH-FL is the example of adopting fuzzy logic in WSN which suggested by B. Mostafa. It uses 'Energy Level' and 'Distance to the BS' as the Fuzzy input parameter [8]. In case of protocol suggested by I. Gupta has energy, concentration and centrality as the parameter [2]. It expects that the energy consumption is reduced by the transmission distance decreases. The TEEN has the data range to collect. This point can make difference

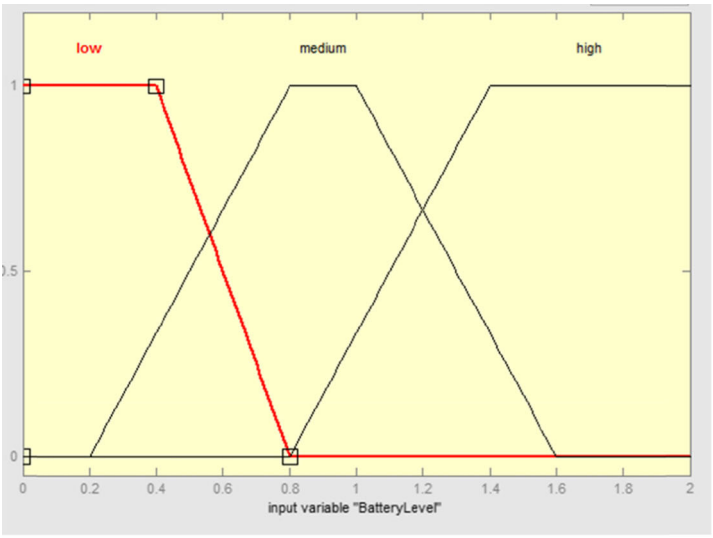


(a) Data Frequency and Battery Level



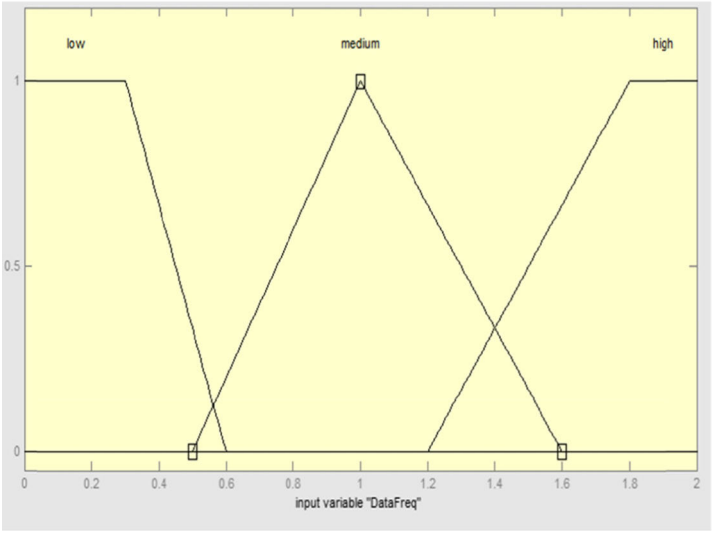
(b) Node Density and Battery Level

Fig. 4 Comparison of two relation surfaces



Level	*Range*
Low	0.0 ~ 0.8
Medium	0.2 ~ 1.6
High	0.8 ~ 2.0

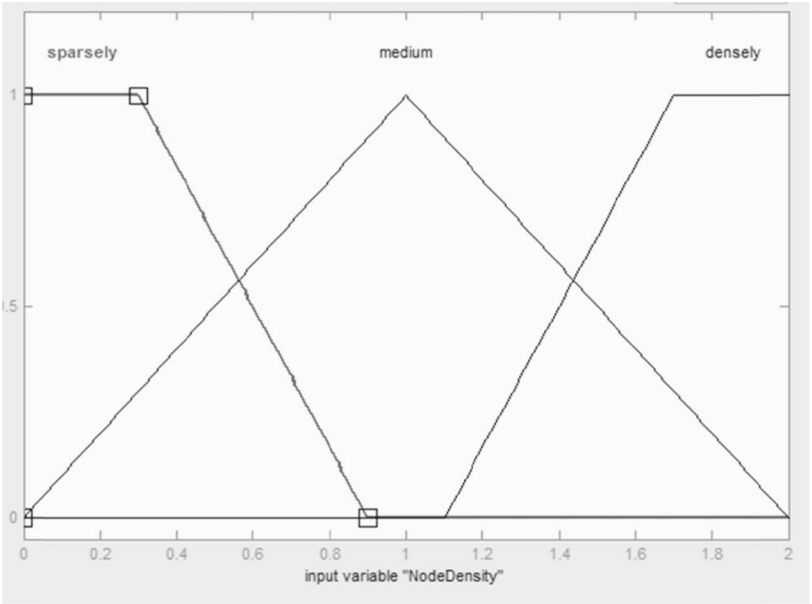
(a) Battery Level



Level	*Range*
Low	0.0 ~ 0.6
Medium	0.5 ~ 1.6
High	1.2 ~ 2.0

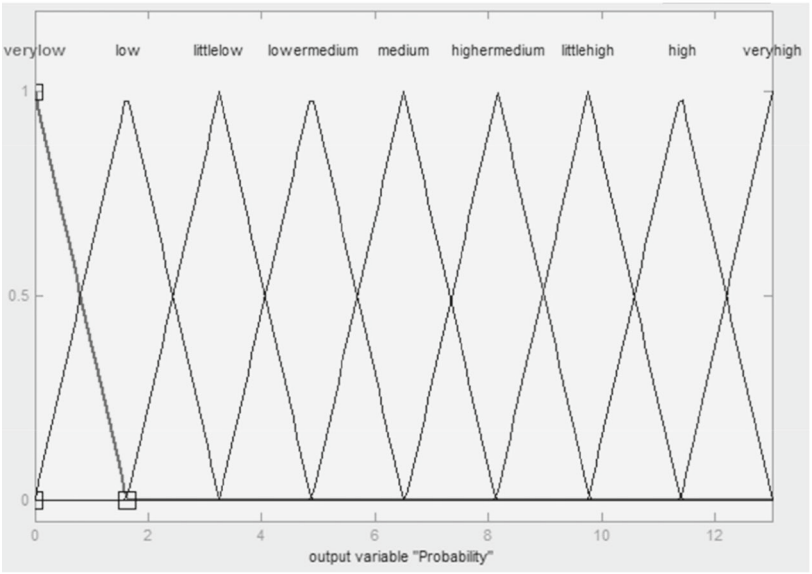
(b) Data Frequency

Fig. 5 Input & output function



Level	*Range*
Sparsely	0.0 ~ 0.9
Medium	0.0 ~ 2.0
Densely	1.1 ~ 2.0

(c) Node Density



(d) CHprob (Probability)

Fig. 5 (continued)

```
FL-TEEN Pseudo code
//For Every Round
FIS_Eval(Node)
{
if(Node.Alive)
{
Node.NodeCnt = Count of close node
Node.BatteryLevel = Node.CurEnergy / Max_Energy * 10;
Node.NodeDensity = Node.NodeCnt / Max_NodeCnt * 10;
Node.DataFreq = Node.SendCnt / Max_SendCnt * 10;

Node.CHprob = Node.BatteryLevel * 2 + Node.NodeDensity + Node.DataFreq * 0.5;
}
}

Elect_CH()
{
for i = 1; i<= nodeCnt; ++i {
DeadNodeCheck(Node(i));
if(isAlive)
{
FIS_Eval(Node(i));
if(rank(Node(i).CHprob) <= (nodeCnt * p))
{// Select CH
This node is CH.
Send AdvMsg include ID
}
else
{
RecvAdvMsg;
Node(i).Destination = AdvMsg.ID;
Send Join_REQ_MSG
}
}
}
}
```

Fig. 6 Pseudo code of FL-TEEN clustering

on the amount of collected data and consumed energy. Therefore we focus on distribution ratio of cluster head according to a data occurrence. It can distributes overhead of cluster head located in high data occurrence place to more place the cluster head.

4 FL(fuzzy logic)-teen

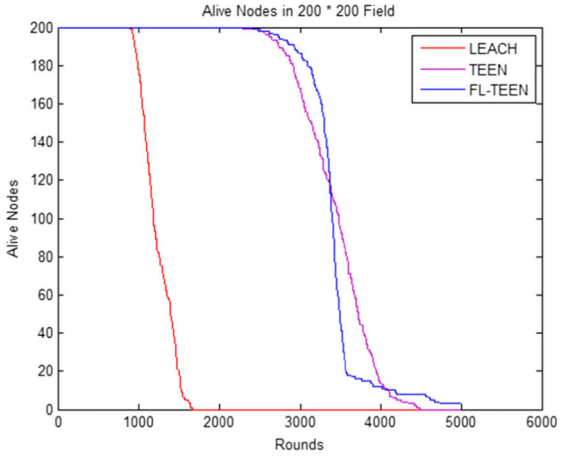
4.1 Introduction for fuzzy logic

The FL-TEEN elects cluster head using deterministic selection method based on fuzzy logic for appropriate and effective cluster head selection [2]. For make choice in range of designers' requirements, the fuzzy inference engine uses three variables and these are Battery Level, Node Density and lastly, Data Frequency. Figure 3 shows the system architecture of fuzzy inference system of FL-TEEN.

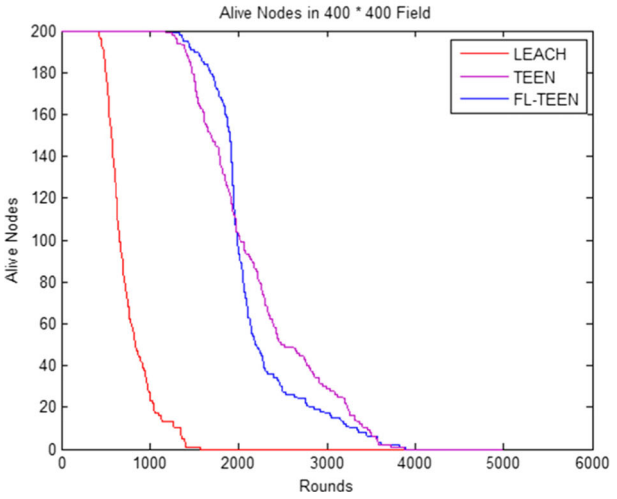
4.2 Fuzzification & defuzzification system

The FL-TEEN uses Fuzzy Inference System for the cluster head election. This selection algorithm calculates the probability which is a cluster head from variables of sensor field and nodes state. It can make a pertinent cluster formation based on the current sensor field state. Table 1 shows Input and Output function variables of the proposed Fuzzy Inference System in this paper.

The Battery Level shows the current residual energy of sensor nodes. This factor is best indicator of sensor node availability. The Node Density is quantified the value of the number of nearby sensor nodes. This factor indicates the amount of collected data indirectly if this node is a cluster head. The Data Frequency is a number of data which satisfied the two thresholds in the previous rounds. This factor indicates for collecting quantity of data from the



(a) 200*200



(b) 400*400

Fig. 7 Number of alive nodes from each protocol in different field size

corresponding area. FIS calculates the CH_{prob} from these input function variables. CH_{prob} is probability of be a cluster head, the higher the input functions is the higher probability. Table 2 is Fuzzy rule table used in this algorithm.

Table 2 shows the relation of input and output function. To visualize the relationship between input function and probability, we draw the surface in Fig. 4. Also, Fig. 5 shows the input & output function in a graph used in Fuzzy Inference System.

The Fuzzy Rule Table and graph simply describe relationship of Input function and probability. The Accurate figures of probability calculated in defuzzification process. This process uses COA(Center of Area) defuzzification method [12] which extract crisp value using center of mass in graph.

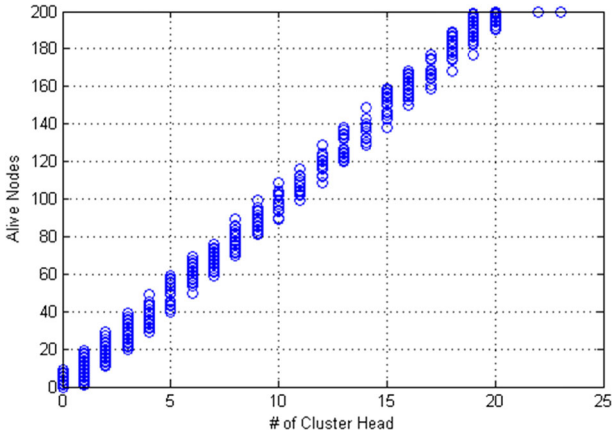


Fig. 8 Cluster head selection aspect per alive node

4.3 Algorithm

In order to calculate the distance to BS from each sensor, the every sensor node has location information. At the beginning of every round, all the node collects variables of input function. In this phase, the nodes gathers the own current battery level, available neighbor node and data collection frequency to calculate the CH_{prob} using the Fuzzy Inference System. After calculating the probability, this protocol elects n cluster heads based on CH_{prob}(n is the expectations value of cluster head). After cluster head is selected, every node begins the data collection and transmission. Sensor node saves sensed value if sensed value greater than H_t or sensed value S_t greater than saved value. The S_t is initialized periodically for prevent failure of data collecting.

Figure 6 is Pseudo code of FL-TEEN Clustering algorithm.

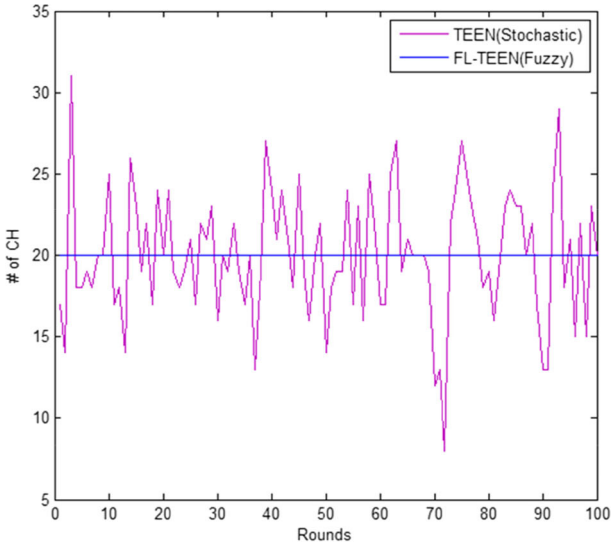
5 Simulation and result

5.1 Simulation environment

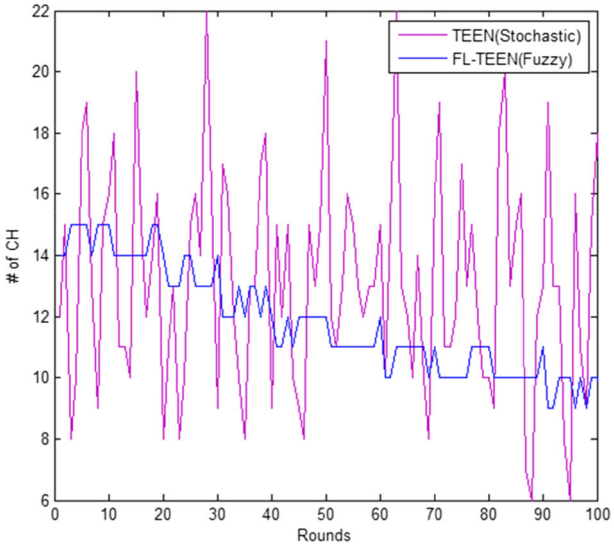
To evaluate the performance of FL-TEEN, we have built the simulation using MATLAB. In order to compare the performance, simulator implement three sensor fields each adopt TEEN, LEACH, FL-TEEN as same parameter. Transmission radio model is used First Order Radio Model. Table 3 and Table 4 shows parameters used in simulator.

5.2 Comparing network lifetime

To verify the network lifetime of proposed protocol, we compare the number of remaining node in two sensor field of different size. Figure 7 presents alive nodes of three routing protocol in the sensor field size of 200 × 200, 400 × 400.



(a)



(b)

Fig. 9 Number of selected cluster head per each round

Table 3 Simulation parameters

Field size	400 * 400
Sensor node	200
Initial energy	0.5 J
Message size	2000 bit
E_{elec}	50nJ / bit
E_{amp}	100 pJ / bit / m^2

Table 4 TEEN parameters

Data range	0 ~ 200
Hard threshold	100
Soft threshold	2

The graph in Fig. 7 indicates that gradient of FL-TEEN increased than TEEN. It means that most nodes have consumed its energy evenly. Therefore the unavailable time of sensor node is become to approximate.

In result of Table 5, the lifetime of FL-TEEN has increased 8 ~ 13% at 80% alive than TEEN. In contrast, the lifetime of FL-TEEN has decreased 2 ~ 18% during remaining node under 50%. This table demonstrates that overall energy consumption became alike and as a result, the lifetime of each node has increased in early phase.

5.3 Analyze energy consumption

In Table 6, we compare the energy consumption in same parameter to verify energy efficiency.

This table indicates the consumed energy in specific round. Each result works out on a same condition. As a result, FL-TEEN reduces energy by 10% than TEEN. In the result of graph in Fig. 7b, the FND of FL-TEEN and TEEN occurs each 1178, 1183 round. In case of FL-TEEN, energy consumption become evenly. It is verified by the graph gradient increased than TEEN. Also, Table 7 is the result of calculation from formula (2) for measure the average of consumed energy at each round.

$$\frac{\text{Total energy before occur First Node Dead}}{\text{Round of First Node Dead occured}} \tag{2}$$

5.4 Analyze result of cluster head selection

To analyze the result of cluster head selection, the simulation verifies the relationship between cluster head election probability and a number of remained node, also verifies cluster head aspect per alive node and expectations.

Table 5 Compare the lifetime of each protocol

Field width	Alive Node	FL-TEEN	TEEN	Increment
200 * 200	80% Alive	3306	3044	+8.61%
	50% Alive	3380	3475	-2.73%
	20% Alive	3428	3789	-9.52%
400 * 400	80% Alive	1680	1483	+13.28%
	50% Alive	1989	2023	-1.68%
	20% Alive	2290	2803	-18.3%

Table 6 Compare consumed energy of n round

	FL-TEEN	TEEN	LEACH
1 Round	0.0526	0.0735	0.1485
10 Round	0.4687	0.6036	1.4820
100 Round	4.9121	5.2403	15.1215
1000 Round	48.3462	52.0223	98.0492

In Fig. 8, it is shown that a number of selected cluster head is proportional to the remaining node. This graph is the result of simulation in $p = 0.1$(probability of cluster head selection). This result indicates the uniformity of cluster head selection in accordance with cluster head selection ratio keep certain level.

These two graphs of Fig. 9 are shown a number of selected cluster head at each round. Graph of (a) is result of before occur dead node, (b) is result of after occur dead node. In graph (a), the stochastic method cannot keep a number of selected cluster head. On the other hand, FL-TEEN elects cluster head in the range of ideal number based on parameter p. The graph (b) shows the aspect of after occurred few dead node. In case of stochastic method, it still cannot keep number of selected cluster head. Also the variation of number of cluster head has increased. However, the case of FL-TEEN makes small variation and elects cluster head in range of p.

6 Conclusion

In this paper, we suggest the adaptive clustering algorithm named FL-TEEN based on TEEN and Fuzzy logic. This protocol changes cluster head selection method to fuzzy logic base for guarantee available of selected cluster head. The most case of protocol based TEEN and LEACH elects the cluster head randomly using stochastic threshold or alternative [14]. The cluster formation which uses the stochastic threshold is hard to form a cluster efficiently. The FL-TEEN calculates election probability from status of sensor field and indicator of sensor nodes lifetime. And this protocol selects the cluster head using this election probability for good cluster formation. We verified the improvement of energy efficiency in appropriate cluster head selection. In result of simulation, FL-TEEN reduces the energy than TEEN about 10% in same parameters. Furthermore FL-TEEN makes uniform energy consumption of sensor node. Also proposed protocol can distribute the overhead in a location of drastic data occurrence to place more cluster head. In conclusion FL-TEEN made an improvement of performance in lifetime of sensor node to change the cluster head selection method. In further research we evaluate the performance in diverse fuzzy input function and change the transmission method to enhance additional energy efficiency.

Table 7 Average of consumed energy per round

Avg. Energy	FL-TEEN	TEEN	LEACH
	0.04722	0.05301	0.14673

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