International Journal of Advanced Smart Convergence Vol.5 No.1 66-72 (2016)
http://dx.doi.org/10.7236/IJASC.2016.5.1.66

IJASC 16-1-10

A Study of Cluster Head Election of TEEN applying the Fuzzy Inference System

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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. The stochastic selection method cannot guarantee available of cluster head. Furthermore, because 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: *WSN(Wireless Sensor Network), BSN(Body Sensor Network), TEEN, Fuzzy logic, Energy efficiency, Hierarchical Routing Protocol*

1. Introduction

The Internet of Things(IoT)is hot issue of IT field recently. The IoT is the one kind of ubiquitous network which explained by 'Every object can communicate and information processing without human command'. To date, the internet cannot be operated by person[1]. While the IoT can make a rational decision by gathered data, it give help to human[1,3]. Also, the IoT is the sensor network system to communicate data like as nervous system. Generally, the Wireless Sensor Network(WSN) is the network system using many sensor node to gather and process data[2]. These sensor nodes are small and low price to make the overall network cost effective[3]. These type of system is usually used in disaster monitoring, military purpose, ubiquitous home network and body sensor network. Especially, In case of body sensor network has many sensor which placed on human body. These sensor collects the body information of target for example blood pressure, heart rate and electromyography. Body Sensor Network consists of few sensor node which collect the human body information and coordinator for collects and processes these data. Thus, the Body Sensor Network must be created in Heterogeneous type network. The collected information transmits to the medical

Manuscript Received: Jan. 18, 2016 / Revised: Jan. 30, 2016/ Accepted: Feb. 15, 2016
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team for monitoring and helping to predict the target health status[4]. 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 making optimized routing protocol which is considered the method for gathering or transmitting data[1,3]. The Threshold sensitive Energy Efficient sensor Network protocol(TEEN) is representative routing protocol of reactive type sensor network[6]. 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 al-ready broadcasted in the cluster formation process. In this paper, we suggest a new clustering algorithm based on TEEN using fuzzy logic in cluster head selection. It improves network stability and uniformity of energy[8]. These increment evaluated by simulation.

2. Related Works

2.1 LEACH

LEACH is representative hierarchical routing protocol based on cluster[5]. 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).

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

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, 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.

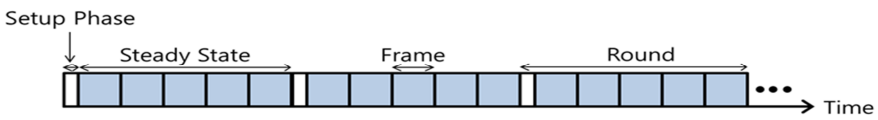
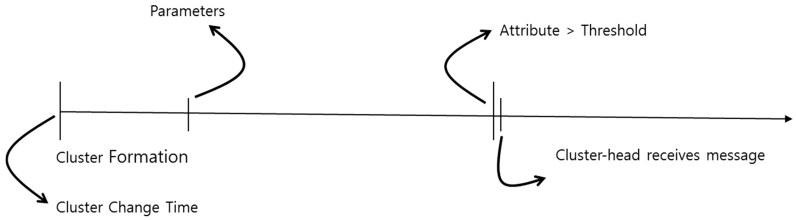


Figure 1. Round timeline of LEACH

2.2 TEEN

TEEN(Threshold sensitive Energy Efficient sensor Network protocol) is the stochastic-hierarchical protocol in the same way as LEACH[6]. This protocol uses the same clustering algorithm of LEACH,

however the sensor node doesn't transmit the sensed data periodically. To filter for data collection or transmission, the TEEN uses two threshold called the H_t(Hard threshold) and S_t(Soft threshold). These two thresholds broadcasted in clustering process. After this broadcast, the first data collection is beginning. If the



sensed data of sensor nodes is bigger than H_t, all the node saves it and it transmits the saved data at own time slot. Figure 2 shows the timeline of TEEN.

Figure 2. 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.

3. Propose of FL(Fuzzy Logic)-TEEN

The FL-TEEN elects cluster head using deterministic selection method based on fuzzy logic for appropriate and effective cluster head selection[7]. For make choice in range of designers requirements, the fuzzy inference engine uses three variables-Battery Level, Node Density, Data Frequency. Figure 3 shows the system architecture of fuzzy inference system of FL-TEEN.

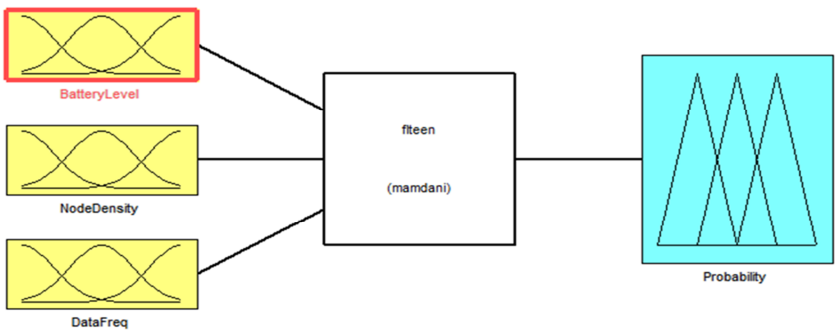


Figure 3. Architecture of FL-TEEN

3.1 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.

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

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 is satisfied the two thresholds in the previous rounds. This factor indicates for collecting quantity of data from the 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.

Accurate figures of probability calculated in defuzzification process. This process uses COA(Center of Area) defuzzification method[9] which extract crisp value using center of mass in graph.

3.2 Algorithm

In order to calculate the distance to BS from each sensor, the every sensor node has location information. At start 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.

4. Simulation and Result

4.1 Simulation Environment

To evaluate the performance of FL-TEEN, we have built the simulation using MATLAB. For 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 2 and Table 3 shows parameters used in simulator.

Table 2. Simulation Parameters

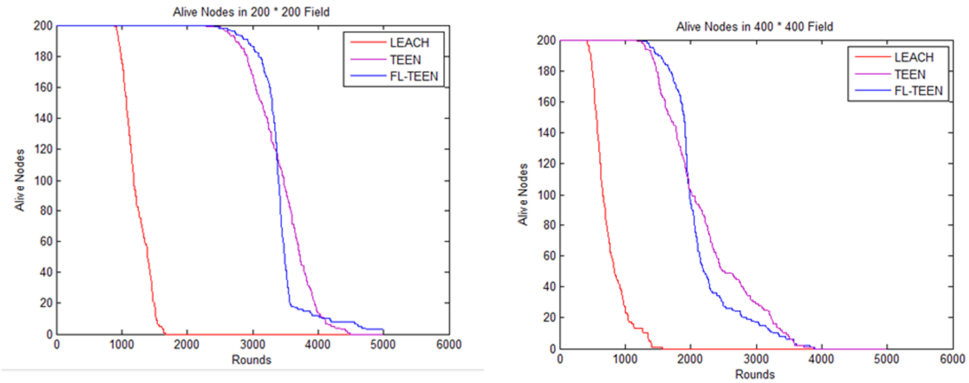
Field Size	400 * 400
Sensor Node	200
Initial Energy	0.5 J
Message Size	2000 bit
E_{elec}	50nJ / bit
E_{amp}	100 pJ / bit / m^2

Table 3. TEEN Parameters

Data Range	0 ~ 200
Hard Threshold	100
Soft Threshold	2

4.2 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 4 presents alive nodes of three routing protocol in the sensor field size of 200x200, 400x400.



(a) 200*200 (b)400*400

Figure 4. Number of alive nodes from each protocol in different field size

The graph in Figure 4 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.

Table 4. 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%

In result of Table 4, 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 means that overall energy consumption became alike and as a result, the lifetime of each node has increased in early phase.

4.3 Analyze energy consumption

In Table 5, we compare the energy consumption as same parameter to verify energy efficiency.

Table 5. 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

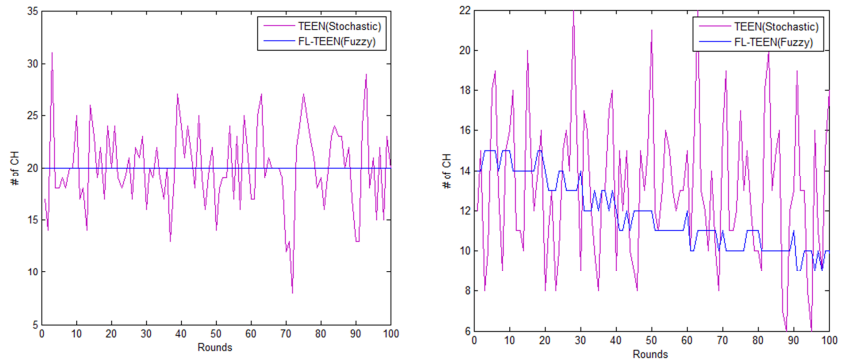
This table indicates the consumed energy in specific round. Each result works out at same condition. As a result, FL-TEEN reduces energy by 10% than TEEN. As result of graph of Figure 4-(b), the FND of FL-TEEN and TEEN occurs each 1178, 1183 round. In case of FL-TEEN, energy consumption become evenly. It is verified by the graph gradient increased than TEEN. Table 6 is the average of consumed energy at each round.

Table 6. Average of Consumed Energy per Round

	FL-TEEN	TEEN	LEACH
Avg. Energy	0.04722	0.05301	0.14673

4.4 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.



(a) (b)

Figure 5. Number of Selected Cluster head per each round

These two graph of Figure 5 shown 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.

5. 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.

References

[1] J.Y. Lee, K.D. Jung, H.M. Jung and D.S. Lee, " Improving the Energy Efficiency of a Cluster Head Election for Wireless Sensor Networks" International of Distributed Sensor Networks, Volume 2014, 2014.

[2] A.K. Singh, N. Purohit and S. Varma, "Fuzzy logic based clustering in wireless sensor networks: a survey", International Journal of Electronics, Vol. 100, pp. 126-141, 2013.

[3] S.R. Baral, Y.I. Song, K.D. Jung and J.Y. Lee, "The Energy Efficient for Wireless Sensor Network Using The Base Station Location", in Proceedings of International Journal of Internet, Broadcasting and Communication, 2015.

[4] C. Otto, A. Milenkovic, C. Sanders and E. Jovanov, "System Architecture of a Wireless Body Area Sensor Network for Ubiquitous Health Monitoring", Journal of Mobile Multimedia, Vol. 1, pp. 307-326, 2006.

[5] W.B. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", in Proceedings of the 33rd Hawaii International Conference on System Science, 2000.

[6] A. Manjeshwar and D.P. Agrawal, "TEEN: A Routing Protocol for Enhances Efficiency in Wireless Sensor Networks", in Proceedings of 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, 2001.

[7] I. Gupta, D. Riordan, and S. Sampalli, "Cluster-head election using fuzzy logic for wireless sensor networks," in Proceedings of 3rd Annual. Communication Networks and Services Research Conference, pp. 255-260, 2005.

[8] Y.I Song, K.D. Jung, J.Y. Lee and S.R. Lee "FL-TEEN : Improved adaptive routing protocol using Fuzzy Logic in Cluster head selection", Contents, Platform, Network and Device & Culture Convergence, AACL 05, pp 219~221, 2015.

[9] N. A. Torghabeh, M. R. A. Totonchi and M. H. Y. Moghaddam, "Cluster Head Selection using a Two-Level Fuzzy Logic in Wireless Sensor Networks", in proceedings of the 2nd International Conference on Computer Engineering and Technology, Vol. 2, pp. 357-361, 2010.