International Journal of Control and Automation
Vol. 8, No. 7 (2015), pp. 385-394
http://dx.doi.org/10.14257/ijca.2015.8.7.37

The Routing Technology of Wireless Sensor Networks Using the Stochastic Cluster Head Selection Method

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Abstract

The most important factor within the wireless sensor network is to have effective network usage and increasing the lifetime of the individual nodes in order to operate the wireless network more efficiently. Many routing protocols have been developed for this purpose. One of these is the LEACH protocol presented by Wendi Heinzelman, which is especially well known as a simple and efficient clustering based routing protocol. However, because LEACH protocol in an irregular network results in a drop in efficiency of the total data throughput, the stability of the cluster is declined. Therefore, to increase the stability of the cluster head, this paper proposes a stochastic cluster head selection method for improving the LEACH protocol. To this end, it proposes a SH-LEACH(Stochastic Cluster Head Selection Method-LEACH) that it is combined with the HEED and LEACH protocol and the proposed algorithm is verified through the simulation.

Keywords: *Wireless Sensor Network, Cluster Head, LEACH, HEED, SH-LEACH*

1. Introduction

In recent trends, the core technology of ubiquitous network is called WSN(Wireless Sensor Network).For data collection and other specific purposes, WSN is in general used in various fields-environment monitoring, tracking target, healthcare systems, hazardous materials, and fire, building internal surveillance, *etc.* [1] WSN consists of the sensor module, sensor nodes with a network module and the base station(BS) that receives data from the sensor node and can be accessed by the user. In general, the sensor node has constraints such as the limited battery, the memory, the arithmetic processing and the communication space *etc*. Also because the transmission medium uses the wireless communications, the bandwidth and transmission speed is limited and means of the power supply is limited, the security is vulnerable. [2] The biggest problem in wireless sensor networks is maximizing its lifetime. Therefore to maximize the life cycle of a wireless sensor network, a variety of studies are now being conducted. The energy efficiency is very important for WSN and the routing protocol is extremely significant in WSN for efficiently transmitting the sensed data to the BS. The routing of clustering-based has a greater advantage in the efficient energy sector and lifetime than the existing wired communication. [3]. After the cluster-based routing protocol is to form a local cluster, the sensed data in the cluster is transmitted to the cluster head(CH) and the routing protocol is able to efficiently ensure that the cluster head performs data collection. In other words, this is divided into small areas called the cluster, and the each cluster has a cluster head that collects the data from the cluster member and transmits to the BS, or acts to pass the

ISSN: 2005-4297 IJCA

upper cluster head. [4] The LEACH and HEED protocol is to have typical routing techniques.

This paper aimed to improve the decision method of cluster for the most important routing algorithm of clustering-based named LEACH. This paper is organized as follows: the related research is mentioned in Chapter 2, the proposed algorithm is presented in Chapter 3, the results of simulation for the proposed algorithms described in Chapter 4, while the conclusion is proposed in the Chapter 5.

2. Related Research

In this chapter, it explained the LEACH, HEED algorithms for typical routing protocols that have been proposed for sensor networks.

2.1. LEACH

LEACH is the abbreviation for Low Energy Adaptive Clustering Hierarchy that the routing protocol proposed in the PhD thesis, "Application-Specific Protocol Architectures for Wireless Networks", by professor Wendi Heinzelman of University of Rochester [5].

The LEACH is a representative protocol of a cluster-based for developing to increase the overall energy efficiency of the sensor network. LEACH is a method wherein a cluster head collects data from member nodes of the cluster, to be processed and transferred to the BS directly. The cluster configuration of LEACH is shown in Figure 1 [6].

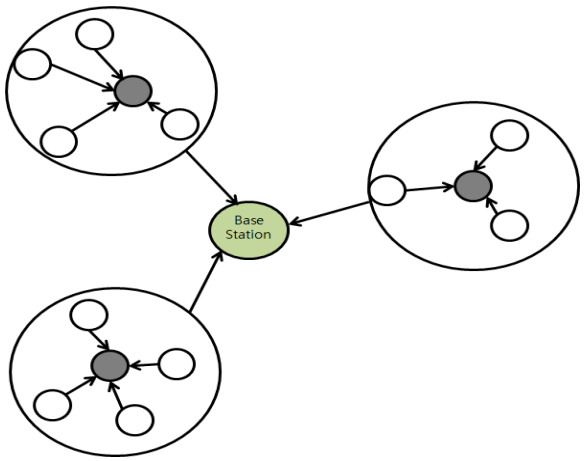

Figure 1. The Cluster Configuration of LEACH

The character of LEACH is that the form of cluster is continuously changed over each time around and the selection of a cluster head is set itself among the sensor nodes in cluster. Through this process, it reduces the energy consumption of the cluster head and the total energy is consumed uniformly because the consumption of total energy is distributed to the overall network. In addition, it improves the energy efficiency of the network by the reducing the number of transmitted data through the data fusion from the cluster head. Then, as the cluster head carries out the data compression process and the data combination, it transmits the less data to the BS. Especially in the case of LEACH, the cluster head is selected in the ratio of the stochastic among sensor nodes; it is not a central management system but a distributed control system. The LEACH consists of the set-up and steady state phase.

In the set-up stage, n times sensor node among of the all sensor nodes selects a random number between 0 and 1, then it ensures that all the nodes becomes the cluster head once by using the probability formula (1) below.

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

In the equation (1), T(n) is the threshold, and G is a set failed to cluster, while r is the current round. If the random number is less than T(n), n times of the sensor node selected the cluster head in the next round. After the cluster head is selected, the cluster head sends a broadcasting message to sensor nodes and collects the cluster members. In steady-phase, the member nodes transmit the data to the cluster head according to the scheduling of forming clusters in the set-up phase. As usual, member node is in a sleep state. When the transmission time is approaching, member node is awakened and data is transferred to CH. At the end, member node goes back to sleep state. Therefore it is possible to reduce energy consumption. However, the node is determined by cluster head one in the cluster head decision process; the node does not have to be a cluster head again. Therefore, in the case of the irregular sensor network, the total amount of data transfer efficiency will drop.

The below Figure 2 presents the LEACH algorithm. [6]

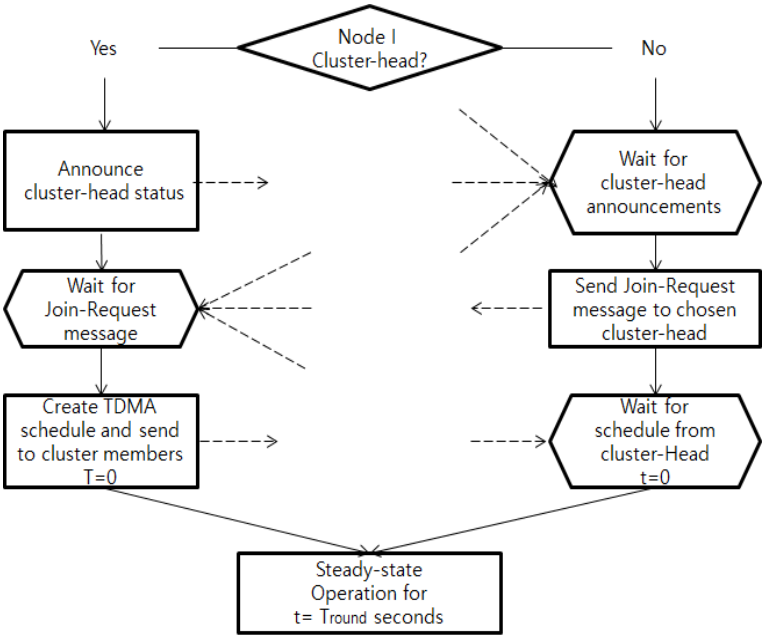

Figure 2. LEACH Algorithm

The advantages of the LEACH:

- Show a significantly higher efficiency than the simplicity.
- Increases the life of the network, acts as a cluster head alternately take role, acts each energy consumption node distributed evenly.

The disadvantage of the LEACH;

- Once a decision has been made about the cluster head, the cluster head does not have to be a cluster head again.
- The total data transfer amount has irregular sensor networks, then the efficiency drops relatively much.

2.2. HEED

HEED is the abbreviation for Hybrid Energy-Efficient Distributed clustering approach, which was proposed by the Osama Younis and Sonia Fahmy of University of Urdue.

Using the amount of remaining node energy, the HEED selects the cluster head and isthe cluster-based wireless sensor network routing protocols [7].

The cluster head selection of HEED does not need to know the energy of all the nodes; it selects a cluster head using only the parameters of the node itself. The cluster head selection stochastic formula of the HEED is the equation (2) that follows [8].

$$CH_{prob} = C_{prob} * \frac{E_{residual}}{E_{\max}} \quad (2)$$

In the formula (2), Cprob is the cluster head node ratio and Emax is the initial energy of node itself, while the residual energy of the node is Eresidual. Then, the expression of (2) is carried out that the selection of the cluster head has the higherprobability for a large residual energy of the own node. These stochastic are calculated, HEED is multiplied by 2 to the probability calculated value, the CH selects the first node to reach the value of "1". Depending on the time, because the energy of all the nodes will be to draw a line descent, the calculated value becomes smaller. The limitation that can't allow most nodes to select a cluster head is present multiplied by 2. However, if all of the energy is similarly low and increased during the multiple of 2, to the cluster head selection probability value disadvantages that may number of nodes the value arrives at 1 is too large, most nodes will be the existing cluster head [8].

The advantages of HEED is as follows;

- There is no need to know the energy of all nodes;additional overhead is not required.
- The amount of data transferred is efficient at irregular sensor networks.

The disadvantages of HEED is as follows;

- Selected cluster head is not guaranteed
- When all of the energy is similarly low, the increase during the multiple of 2 to the cluster head selection probability value has the disadvantage that the number of nodes arriving at 1 will be too large, leading to the possibility that most nodes will become existing cluster heads.

3. The Proposed Algorithms

3.1. LEACH Problem

During the cluster head selection process in LEACH, once a random node is selected to be a cluster head, this node never would be able to get selected again unless every node took turns for the cluster head. Additionally, a network with irregular transmission quantity data must have decrease in effectiveness. Consequently, the LEACH shows cluster instability. In order to develop this issue, we are suggesting the application of LEACH on a stochastic method of HEED.

3.2. Stochastic Methods HEED

While HEED is selecting the cluster head, it uses a stochastic method called CHprob to determine the cluster head. This is proved to be effective in irregular sensor network, but it causes error in data flow and network composition process due to complicated routing technique.

3.3. New Stochastic Cluster Head Selection Method

The study introduces a new cluster head selection system within adapting a stochastic cluster head method based on LEACH. Unlike selecting each node in turns, the stochastic

formula below (3) applies a random number of each node and selects it to be the cluster head.

$$CH_{prob} = C_{prob} * \frac{E_{residual}}{E_{\max}} * \frac{C_{prob} * r}{1 + CH_{cho} \bmod \frac{1}{C_{prob}}} \quad (3)$$

The formula (3) is the improved cluster head stochastic function of HEED. As time flows, energy level decreases in every node which then may not be selected as cluster head. Therefore regarding the increase of rounds, it multiplied a number of rounds to keep a certain level of stochastic. CHcho is a parameter that stands for the number of nodes that are selected as cluster head till the present round. And add this to denominator for constant rate at the most. Moreover, mod function is used to reduce the stochastic when there are lots of selected nodes of cluster head until the present round. Nevertheless, if there are few selected nodes of cluster head, the stochastic increases. This proposed algorithm is shown Figure 3 as below.

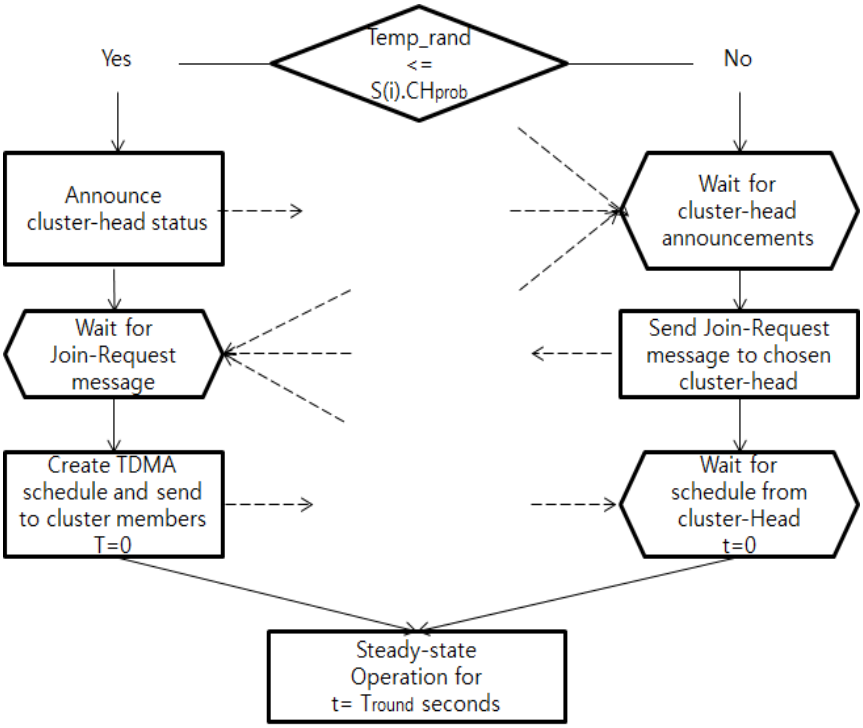

Figure 3. Proposed Algorithm

4. Simulation and Discussion

4.1. Experimental Environment

In this paper, a proposed stochastic cluster head selection method was performed through the use of Matlab simulator. The sensor node energy consumption simulation is shown in Figure 3. The parameter of used energy consumption is in Table 1 and Table 2 demonstrates the major variables that were addressed in this thesis. The simulation proceeded under the circumstance of each node having an equal amount of initial energy.

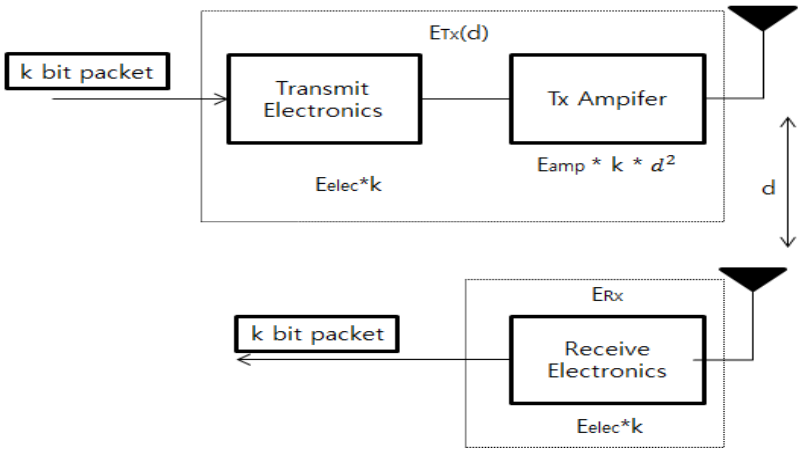

Figure 4. Energy Consumption Model

Table 1. Energy Consumption Model Parameters

Parameters	Set
n	100
C_{prob}	0.10
ϵ_{mp}	100pJ/bit/m2
E_{max}	0.5J
E_{TX}	50nJ/bit
E_{RX}	50nJ/bit

Table 2. Main Parameters that are used in the Simulation

Parameters	Description	Parameters	Description
E_{elec}	Circuit energy consumption	E_{DA}	Aggregation
ϵ_{fs}	Free space loss	ϵ_{mp}	Multi-path loss
n	Number of node	C_{prob}	Cluster head ratio
E_{TX}	Transfer energy	E_{RX}	Received energy

4.2. Simulation Results

When the value of Cprob is 0.1 with 100X100 sensor field, the following figures and simulation result came out on the round of 2000. Figure 5 and 6 shows thesensornode and the cluster head when the initialround and roundtwice.

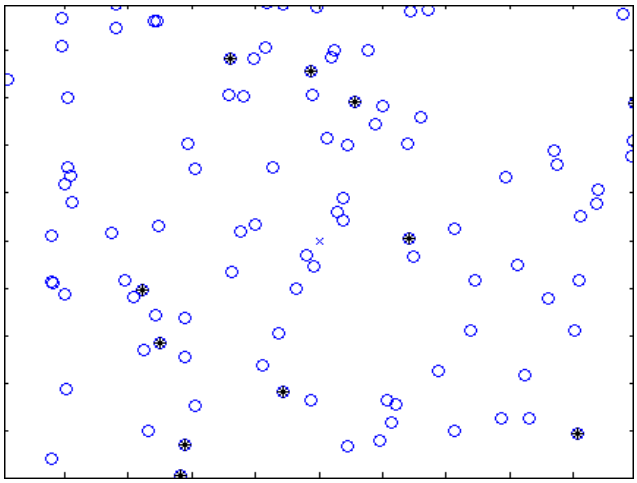

Figure 5. Thesensornode and Hecluster Head (Round 1)

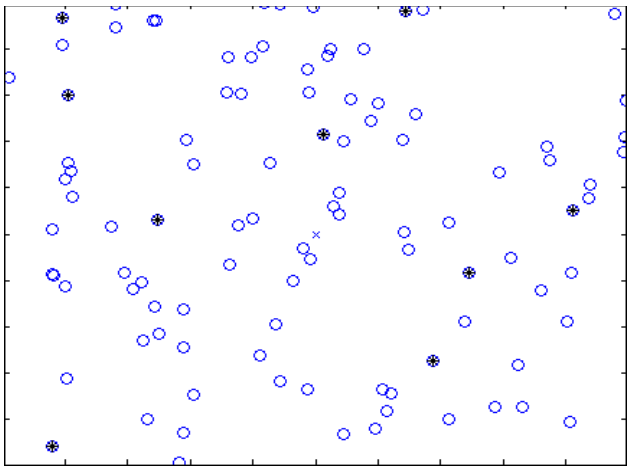

Figure 6. Thesensornode and the Cluster Head (Round 2)

The cluster head is determined according to the formula (3)as shown in Figures 6 and 7.

Next, Figures 7 and 8 show the results for the surviving node and energy consumption for LEACH, HEED and SH-LEACH.

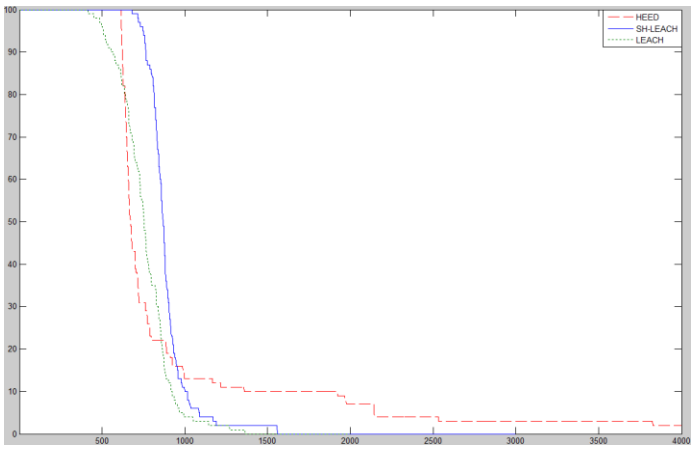

Figure 7. A Comparison of the Surviving Node of the LEACH, HEED and SH-LEACH

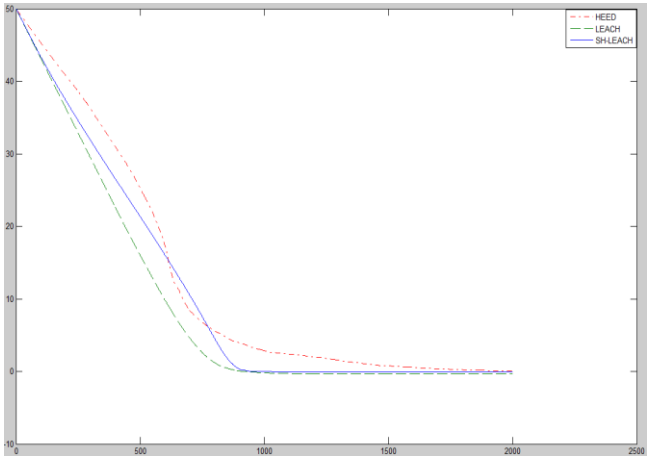

Figure 8. A Comparison of the Total Energy Consumption of the LEACH, HEED and SH-LEACH

The results of Figures 7 and 8 are given in Table 3. The FND of the proposed SH-LEACH has improved the efficiency over 50%, 11% as compared to LEACH, HEED.

Table 3. The Comparison HEED, LEACH and SH-LEACH by Round

0.5J	LEACH(Round)	HEED(Round)	SH-LEACH(Round)
First Node Dead	417	618	689
50% Node Dead	753	746	869
80% Node Dead	864	893	933
90% Node Dead	917	1369	1001

5. Conclusion

The typical type of cluster based algorithm LEACH and HEED were investigated in this paper. Within the LEACH based and through adapting a stochastic cluster selection of HEED, we introduced a new stochastic method of selection on cluster head. The proposed algorithm has the disadvantages that it does not ensure the number of cluster heads and uses up more energy than LEACH although it has uniform energy consumption of node; the evaluation demonstrated better outcome when comparing lifetimes with the existing method. Besides, it also can slow down the speed of the first dead node occurrence.

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