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Improvement of Network Lifetime by Replacing Cluster Head in Cluster-based Wireless Sensor Network

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It is very difficult to replace or recharge the energy of the wireless sensor node because the nodes are widely deployed or the number of them is difficult to access. Since more than a certain number of sensor nodes consume battery energy in a specific network, the network does not function. Therefore, in order to minimize the energy consumption of the sensor node and maintain the network for a long time, many routing protocols have been proposed. The LEACH protocol in a cluster-based protocol elects CH based on threshold equation. After that, by dividing the sensor field into clusters based on CH, energy dissipation of nodes in the sensor field can be dispersed, which has the advantage that the network energy efficiency can be improved. However, since the CH is elected by the critical equation, an inefficient Cluster may be formed or the position of the CH may be inefficient. In Cluster-based protocols, the energy consumption depends on the location of the CH. In this paper, we try to improve the network lifetime by changing the CH.

Keywords: WSN; CH; lifetime; cluster; replace

I. INTRODUCTION

WSN (Wireless Sensor Network) (Akyildiz *et al.*, 2002) consists of sensor nodes with processing, communication (Abbas & Hong, 2017; Choi, 2017) and sensing functions. Each sensor node basically consists of a processor, a limited energy such as a battery, a transceiver and a low-capacity memory (Lee *et al.*, 2014). It is important to use the limited energy of the sensor node efficiently because it is difficult to replace or recharge the sensor nodes' batteries because the sensor nodes of the WSN are mainly deployed in a place that is difficult for human access. Therefore, one of the most important considerations in WSN design is to optimize the energy consumption of each node to increase the energy lifetime of the network. (Youn *et al.*, 2017; Kim *et al.*, 2015; Kim, 2016; Santosh *et al.*, 2010).

If all the wireless sensor nodes are consumed, the node cannot be used. If you cannot use more nodes, the network will not work properly. Therefore, various protocols have been proposed for keeping the network for a long time while minimizing the energy consumption of the node.

A typical Cluster-based protocol is the LEACH protocol. LEACH protocol consists of a set-up phase and a steady state phase. The LEACH protocol randomly elects a CH (Cluster Head node) through a stochastic threshold according to the probability at the set-up stage. The elected CH forms a Cluster together with neighboring nodes.

In the steady state, data is transmitted and received within the Cluster, and the CH receives all the data in the Cluster and performs data aggregation processing to transmit the data to the BS (Base Station). The LEACH protocol is a cluster-based protocol, and CH is elected by the threshold equation. This can increase the energy efficiency of the network by distributing the energy consumption of the nodes. However, since CH is elected by the threshold equation, clusters are not always efficiently formed.

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Depending on the location of the CH in the cluster, it can be an inefficient cluster. For example, if the node farthest from the BS in the cluster is elected as the CH, a member node is transmitted in the opposite direction to the BS. In this paper, after constructing a cluster in the LEACH protocol, we intend to improve the network lifetime by changing the CH to an appropriate node in the cluster.

II. RELATED WORK

A. Clustering algorithm

Cluster-based protocols typically involve the formation of sensor Clusters into multiple Clusters. The reason for dividing into Clusters is to reduce the data of the packets by merging the data, and to reduce the number of transmissions and energy consumption of the nodes. Each Cluster has one CH. Each CH collects data of all the member nodes in the Cluster, processes the collected data, and transmits the collected data to the BS (Chong & Kumar, 2003; Mahajan & Dhiman, 2016; Jun *et al.*, 2018). Figure 1 shows the basic hierarchical structure of the Cluster.

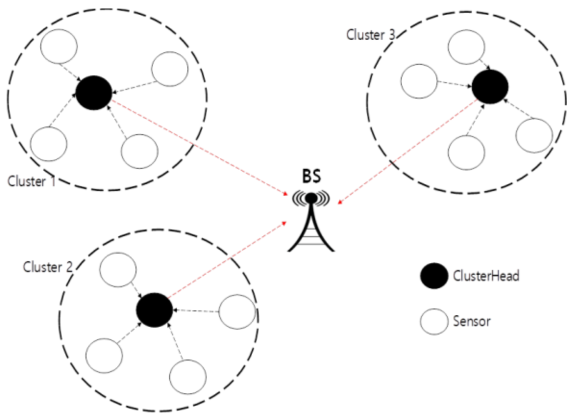

Figure 1. Hierarchical structure of a Cluster in Wireless Sensor network

First, the measured data of member nodes in the Cluster are collected and transmitted to the CH. The CH aggregates the data of the member nodes, processes them, and transmits them to the BS. By integrating similar information between adjacent nodes, it is possible to reduce energy waste due to redundant transmission (Sahana, 2014). However, when a node is continuously elected as a CH or when a CH transmits data to a remote BS, the CH consumes more energy than the member node. To solve this problem, the LEACH protocol (Heinzelman *et al.*, 2018) which is a Clustering-based protocol, has been proposed.

B. LEACH Protocol

The LEACH protocol is a representative Clustering-based protocol proposed by Wendi B. Heinzelman. The LEACH protocol consists largely of a set-up phase and a steady-state phase. In the set-up phase, the CH is elected by the stochastic threshold. Then, the elected CH forms a Cluster with surrounding sensor nodes. The CH informs the member nodes of TDMA schedule. In the steady state, the member nodes in the Cluster transmit data to the CH based on the TDMA schedule. And the CH processes the received data and itself data by aggregating. The CH directly transmits to the BS by a CDMA method. Figure 2 shows the structure of the LEACH protocol.

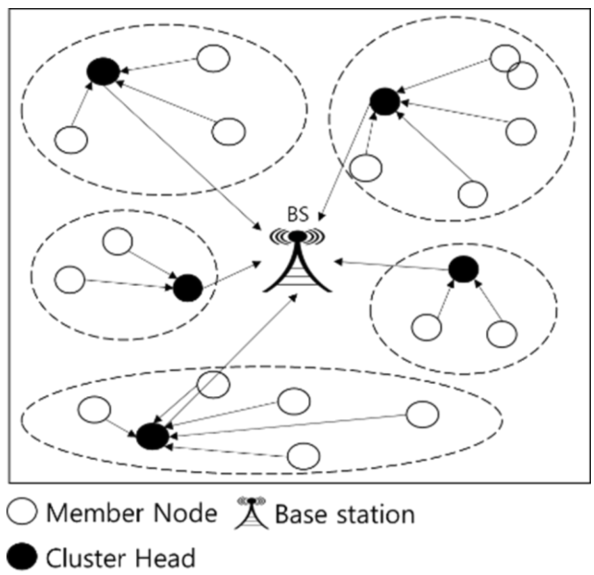

Figure 2. Structure of LEACH Protocol

The LEACH protocol has the advantage of distributing the energy consumption of the network by electing all the nodes as CH once. However, since the LEACH protocol randomly elects the CH by the stochastic threshold, there is a problem that the distance between the member node and the CH may become long. Figure 3 shows a flowchart of the LEACH Protocol.

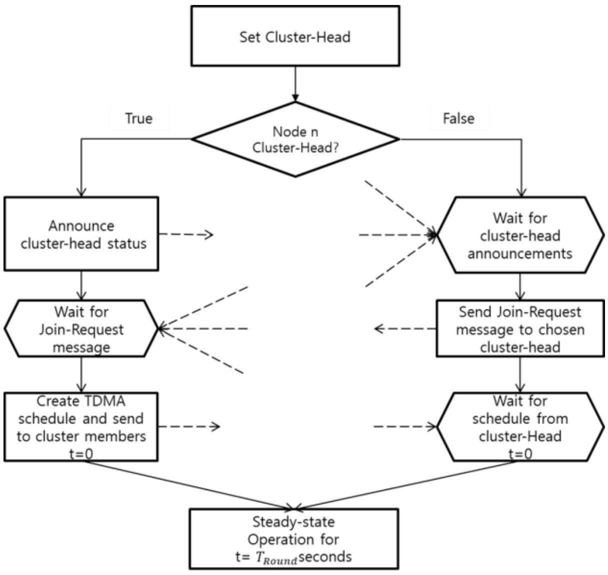

Figure 3. Flow chart of LEACH Protocol

C. Equal probability CH election method

The number n_{CH} (number of CH) close to $elec_{CH}$ = N (*number of sensor node*) * p (*CH election probability*) is selected on average by using the inequality probability CH selection method. The n_{CH} is not constant because every node rounds out the CH according to the threshold *T(n)* equation only once. Sometimes too many CH elected, or no CH elected at all. This may be less efficient than before clustering. To improve this, we use Equal probability CH election method so that the same CH is elected every round. Equal probability CH election method elects CH using the threshold *T(n)* equation until the n_{CH} becomes $elec_{CH}$ every round;

If n_{CH} is larger than k, then it is sorted in the order of high energy and only CH is elected.

If n_{CH} is less than $elec_{CH}$, the CH is elected until it becomes $elec_{CH}$.

Figure 4 is a flowchart of equal probability CH election method.

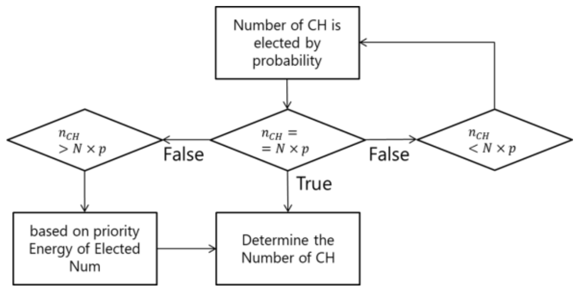

Figure 4. Flowchart of Equal probability CH election method

Figure 5, Figure 6 and Table 1 show the number of CH per round when the number of sensor node N is 100 and CH election probability p is 0.1.

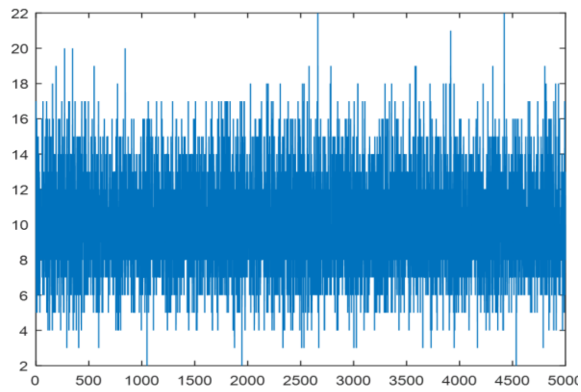

Figure 5. Number of CH per round (Inequal elect)

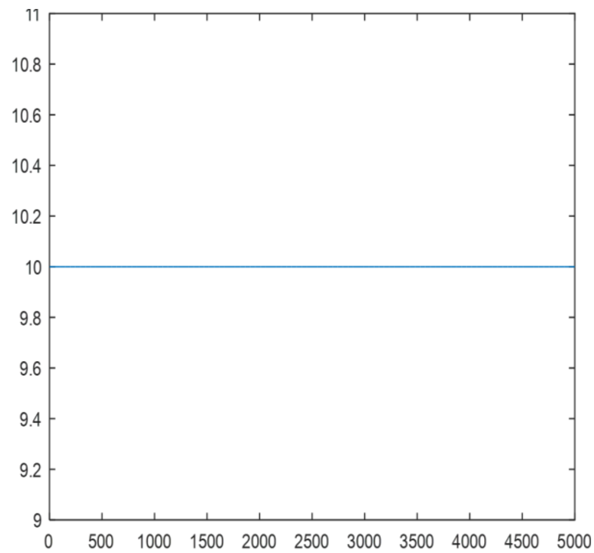

Figure 6. Number of CH per round (qual elect)

Table 1. Number of CHs per round

Round r	Inequal elect CH	Equal elect CH
1	16	10
2	11	10
3	13	10
4	11	10
5	11	10
6	7	10
7	11	10
8	10	10
9	4	10
10	6	10
Average	10.00	10.00

III. PROPOSED METHOD

When Clusters are configured in the LEACH protocol, energy consumption depends on the location of the CH. Figure 7 shows an example of the best- and worst-case location of CH. In the worst case, network energy consumption is high and network life is shortened.

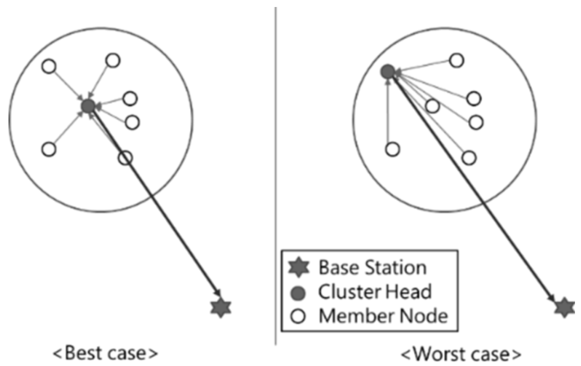

Figure 7. Best case and Worse case

After the Cluster is configured, we improve the network lifetime by changing the CH.

A. Case 1

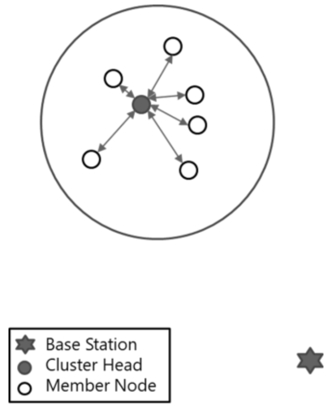

Figure 8. Case 1

In the first case, change the CH to the node with the lowest sum of the distances between the nodes in the Cluster. This is the node near the center of the Cluster. If you change the CH to a node near the center of the Cluster, you can minimize the distance traveled by the member nodes. We compared the network lifetime of existing LEACH Protocol and Case 1 method.

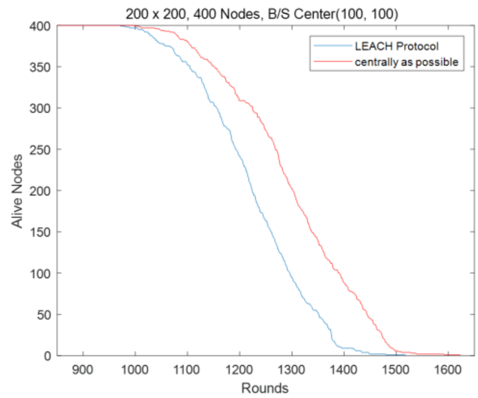

Figure 9. Network lifetime comparison: LEACH Protocol and Case 1

Figure 9 and Table 2 show that the FND has increased in Case 1 compared to the existing LEACH Protocol.

Table 2. First Node Dead comparison: LEACH Protocol and Case 1

	FND
LEACH Protocol	972
CH centrally as possible	999 (2.7% ▲)

B. Case 2

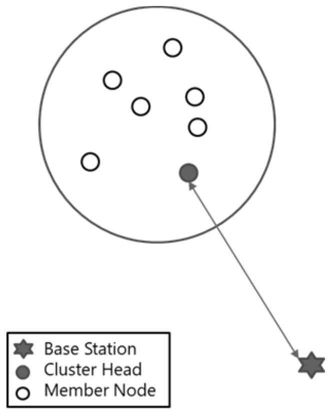

Figure 10. Case 2

In the second case, the CH is replaced with the node closest to the BS. If the CH is changed to a node close to the BS, the transmission distance of the CH can be minimized.

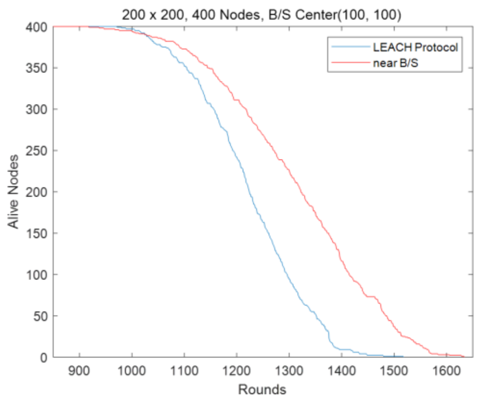

Figure 11. Network lifetime comparison: LEACH Protocol and Case 2

According to Figure 11 and Table 3, when improved as in Case 2, the FND was reduced compared to the existing LEACH Protocol, but the overall network lifetime increased.

Table 3. First Node Dead comparison: LEACH Protocol and Case 2

	FND
LEACH Protocol	972
CH centrally as possible	918 (6% ▼)

Cases 1 and 2 are divided into best and worst cases for the location of CH when the cluster is configured with the LEACH protocol. In case 1 the CH is selected at the center of the cluster. Changing CH to a node near the center of the cluster minimizes the distance that the member node travels. The performance of the corresponding cases is shown in Figure 9 and Table 2. Case 2 indicates that CH is not selected at the center of the cluster. Therefore, changing CH to a node close to the BS minimizes the transmission distance of CH. The performance of the corresponding cases is shown in Figure 11 and Table 3.

C. Propose

In the case where the Cluster node is changed to the CH (Case 1), the FND is better than the existing LEACH Protocol. In case of the node closest to the BS being changed to the CH (Case 2), the LND is better than the existing LEACH Protocol. Figure 12 shows a graph comparing the network lifetimes of Case 1 and Case 2.

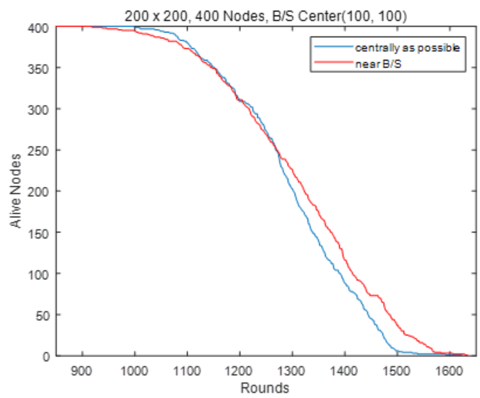

Figure 12. Network lifetime Comparison: Case 1 and Case 2

The proposed method is as follows:

Step 1: When the CH roll is replaced by the method of Case 1, the total transmission distance is obtained.

Step 2: When the CH is replaced by the method of Case 2, the total transmission distance is obtained.

Step 3: After comparing the values of Step 1 and Step 2, replace the CH with the Case method with a short total transmission distance.

IV. SIMULATION AND RESULTS

In this page, we are simulated with MATLAB to evaluate the performance of protocols. The table 4 indicates the parameters of radio model and table 5 indicates the parameters of this simulation.

Table 4. Radio Model Parameters

Parameter	Value
Energy dissipation to run the radio device (E_{elec})	50 nJ/bit
Data Aggregation (E_{DA})	50 nJ/bit/signal
Transmitter Amplifier (ε_{fs})	10 pJ/bit/m^2
Transmitter Amplifier (ε_{mp})	0.0013 pJ/bit/m^4

Table 5. Simulation Parameters

Parameter	Value
Number of Sensor Node (N)	400
Sensor Field (M)	200 x 200
Initial Energy (e_0)	0.5J
Position of BS	Center (100, 100)
Size of Packet (l)	2000 bit

Assuming that the sensor field is 200 x 200 and the BS's position is in center (100, 100). Sensor nodes are arranged as shown in Figure 13. The Table 6-8 and Figure 14 show the results of network lifetime comparison using the above simulation parameters.

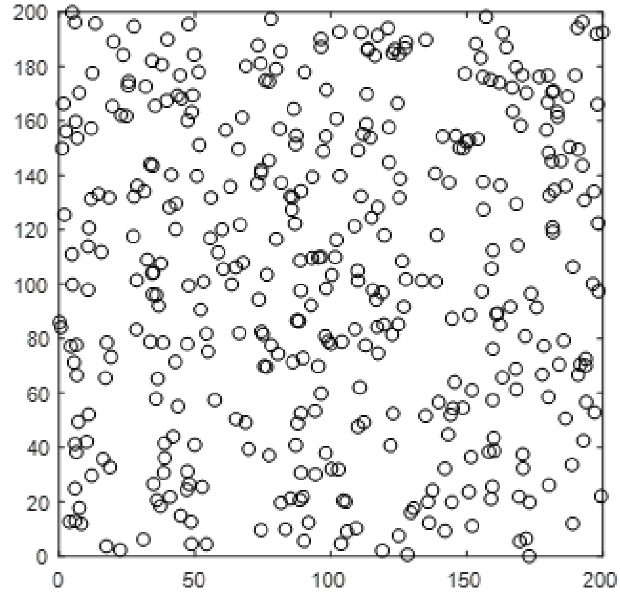

Figure 13. Node placement in Sensor Field

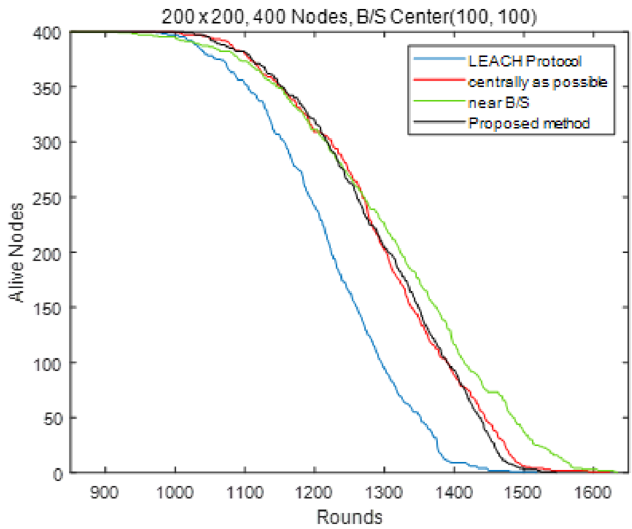

Figure 14. Network lifetime comparison

Table 6. First Node Dead comparison

	FND
LEACH Protocol	972
Case 1 (CH centrally as possible))	999 (2.7% ▲)
Case 2 (CH near BS)	918 (6% ▼)
Proposed Method	**1013 (4.2% ▲)**

Simulation results show that the CH located at the very center of the Cluster, known as Case 1, has a network lifetime of up to 2.7% greater than the LEACH protocol. When CH is near the BS, known as Case 2, has a 6%

reduction in network life over the LEACH protocol. The proposed method has increased network lifetime up to 4% over LEACH Protocol.

Table 7. 20% Node Dead comparison

	80% Node Alive
LEACH Protocol	1137
Case 1 (CH centrally as possible))	1192 (4.8% ▲)
Case 2 (CH near BS)	1191 (4.7% ▲)
Proposed Method	**1201 (5.6% ▲)**

When 80% of the total nodes survived, the CH in the center of the Cluster, known as Case 1, increased the network lifetime by 4.8% over the LEACH protocol. When CH is near the BS, known as Case 2, has a 4.7% increase in network life over the LEACH protocol. The proposed method has a 5.6% increase in network lifetime over LEACH Protocol.

Table 8. 50% Node Dead comparison

	50% Node Alive
LEACH Protocol	1224
Case 1 (CH centrally as possible))	1303 (6.5% ▲)
Case 2 (CH near BS)	1323 (8.1% ▲)
Proposed Method	**1307 (6.8% ▲)**

When 50% of the total nodes survived, the CH in the center of the Cluster, known as Case 1, increased the network lifetime by 6.5% over the LEACH protocol. When CH is near the BS, known as Case 2, has an 8.1% increase in network life over the LEACH protocol. The proposed method has a 6.8% increase in network lifetime over LEACH Protocol.

V. CONCLUSION

In a Cluster-based protocol, the energy consumption depends on the CH location in the Cluster. Replacing CH in a Cluster can improve network lifetime. In this paper, we compare the network lifetime of the CH located at the center of the cluster and the network lifetime of the CH close to the BS and improve the lifetime of the network by utilizing the merits of both.

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