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EL-SEP: Improved L-SEP by adding Single-hop layer

WooSuk LEE[1], Kye-Dong Jung[2], Jong-Yong Lee[2†]

[1]Department of Plasma Bioscience and Display, KwangWoon University Graduate School, Seoul, Korea
[2]Ingenium college of liberal arts, KwangWoon University, Seoul, Korea
{ leewoosuk, gdchung, [†]jyonglee }@kw.ac.kr

Abstract

Wireless sensor nodes have limited energy, so it is important to optimize energy consumption to preserve network lifetime. Various protocols have been proposed for this purpose. LEACH protocol and SEP are the representative protocols. These protocols become less effective as the Sensor Field becomes wider. To improve this, MR-SEP and L-SEP were proposed. These protocols increase the energy efficiency by dividing the Sensor Field into layers and reducing the transmission distance. However, when dividing a layer, there are cases where it is divided inefficiently, and a node within a certain range from a Base Station has a better transmission efficiency than a direct transmission method using a cluster method.

In this paper, we propose a Single-hop layer for L-SEP to improve inefficient layer division and near node transmission efficiency. When the larger the Sensor Field, the better the performance of the proposed method by up to 87%. The larger the sensor field, the more efficient the proposed method is over the conventional method. That is, the proposed method is suitable for the wide Sensor Field.

Keywords: WSN, Layer, Clustering, Cluster, Energy, SEP.

1. Introduction

Wireless Sensor Network (WSN) [1,2,3] is a network in which sensor nodes in a Sensor Field wirelessly communicate with each other. Wireless sensor nodes have limited power such as battery without separate power source. Wireless sensor network have heterogeneous networks, each of which has the same amount of energy, and heterogeneous networks, each of which has a different amount of energy. In addition, various protocols have been proposed to solve the problem of the lifetime of each wireless sensor network.

A representative network lifetime improvement protocol is the LEACH protocol [4], and SEP [5] suitable for heterogeneous wireless sensor networks is proposed based on the concept of the LEACH protocol. The LEACH protocol uses the Cluster Head selection probability to cyclically select the Cluster Head to equalize the energy consumption of the sensor nodes. However, there is a problem that the LEACH protocol does not always produce an ideal cluster. SEP is basically based on heterogeneous wireless sensor network and

operates similar to LEACH protocol, but it has different probability of Cluster Head selection depending on node type. This allows the Advanced node with more energy to be selected as the Cluster Head as possible. However, as the Sensor Field becomes wider, SEP becomes less energy efficient. MR-SEP [6] suitable for a wide-area Sensor Field has been proposed to improve this. MR-SEP improves network life by reducing the distance of distant sensor nodes. That is, we added the concept of Multi-hop routing to SEP. However, since the layer is unconditionally divided on the basis of nodes that are far from the Base Station, the layers can be inefficiently divided. To improve this, L-SEP [7] was proposed. The L-SEP divides the layer with the MR-SEP, but divides the base of the layer by the distance from the nearest node to the farthest node. However, in the some case of L-SEP, layers may be divided inefficiently. If only one or more nodes are close to the Base Station depending on the node distribution, then the layer is inefficient. In addition, it is more efficient to use the direct transmission method than the cluster algorithm in a certain range of nodes from the Base Station.

In this paper, we improve the transmission efficiency of nodes near the Base Station by adding a Single-hop layer to L-SEP. By designating a certain range as a Single-hop layer, the case where a layer is inefficiently divided by nodes near the Base Station is also improved. In Section 2, the related research, in Section 3, the proposed method, in Section 4, the Simulation and Results, and in Section 5, the Conclusions.

2. Body

2.1. LEACH (Low Energy Adaptive Clustering Hierarchy) Protocol [4]

The LEACH Protocol is a Clustering Protocol based hierarchical routing protocol. The Sensor Field is divided into clusters, and there is one Cluster Head node for each divided cluster. The LEACH protocol is divided into a set-up phase in which Cluster Head election is performed and a steady-state phase in which transmission is actually performed. The Cluster Head collects the data of the member nodes in the cluster and transmits it, which consumes a lot of energy. For uniformly distributing energy consumption, the LEACH Protocol changes the cluster every round.
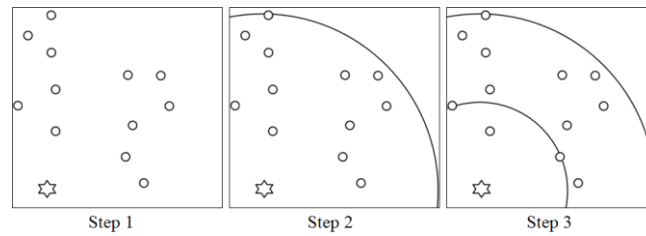
2.2. SEP (A Stable Election Protocol for clustered heterogeneous wireless sensor networks) [5]

SEP is suitable for heterogeneous networks and gives a different Cluster Head probability equation depending on the type of nodes. Heterogeneous networks are different from homogeneous networks in which all nodes have the same energy. A node with more energy than a normal node is called an Advanced node. In case of Cluster Head election, it is selected by probability equation like LEACH Protocol. In case of SEP, weight is applied to Advanced node with higher energy to increase the selection probability.

The LEACH protocol and SEP have a disadvantage in that they are not efficient in a wide Sensor Field because they do not consider the transmission distance. To improve this, MR-SEP was proposed.

2.3. MR-SEP (Multi-hop Routing SEP) [6]

MR-SEP is the addition of Multi-hop routing concept to SEP. The MR-SEP divides the Sensor Field and reduces the transmission distance by Multi-hop transmission, thereby reducing transmission energy. This can improve serious energy consumption in a large Sensor Field, one of the problems of SEP. The process of dividing the Sensor Field is shown in Fig. 1.
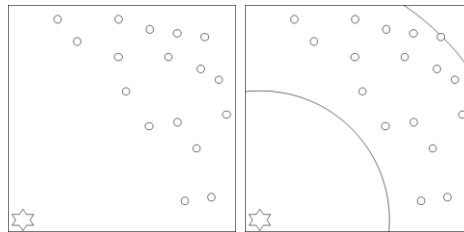
Figure 1. The process of dividing a layer

After dividing a layer, each sensor node constitutes clusters and a Cluster Head in each layer. After all the member nodes in all clusters transmit data to the Cluster Head, the Cluster Head of the outer layer transmits to the near Cluster Head of the inner layer. The Cluster Head of the inner layer transmits all the data including the data of the outer layer to the Base Station.
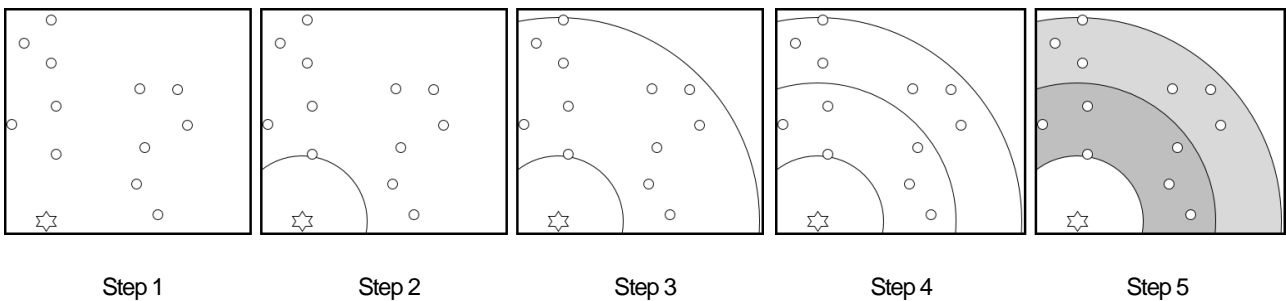
2.4. L-SEP (Layered SEP) [7]

MR-SEP solves energy consumption problem in wide Sensor Field which is a problem of SEP through Multi-hop transmission method, but it is not always efficient. Because it always divides the layer with respect to the node far from the Base Station regardless of the distribution of the nodes. In other words, as shown in Fig. 2, it may be divided inefficiently. In the figure, the star shape is the Base Station and the circle shape is the sensor node.

Figure 2. Inefficient layer partitioning of MR-SEP

In order to solve this problem, L-SEP has been proposed. The process of dividing the sensor area is shown in Fig 3. In this case, the layer in which the divided layers are close to the Base Station is called an inner layer, and the layer in light gray which is a layer far from the Base Station is called an outer layer

Figure 3. The process of dividing a layer

After the layers are divided as described above, a Cluster Head is selected for each layer to form a cluster.

In the same way as the conventional MR-SEP, the transmission method transmits the Cluster Head of the outer layer to the Cluster Head of the inner layer, and the Cluster Head of the inner layer transmits the data to the Base Station. As can be seen in Figure 4, comparing the layers of MR-SEP and L-SEP. It shows that L-SEP is more efficiently divided.
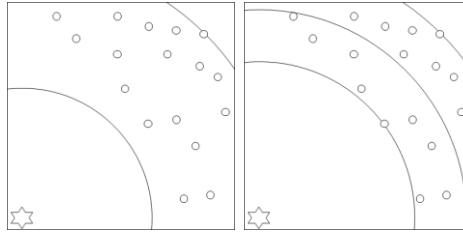

Figure 4. Comparing the layers of MR-SEP and L-SEP

3. Proposed Method

However, in case of L-SEP, as shown in Fig. 5, if there are a few nodes very close to the Base Station, the layer can be inefficiently divided.
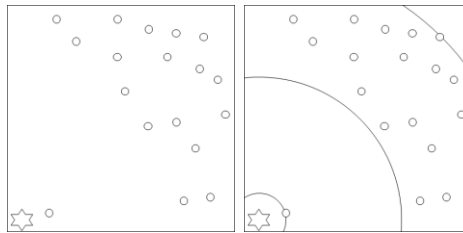

Figure 5. Inefficient dividing layer of L-SEP

Since the density difference between the inefficiently divided inner layer and the sensor nodes distributed in the outer layer is large, the data transmitted from the outer layer cluster is overloaded to the inner Cluster Head. Also, as shown in Fig. 6, the direct transmission method is better than the clustering method in the case of nodes located within a certain range from the Base Station.
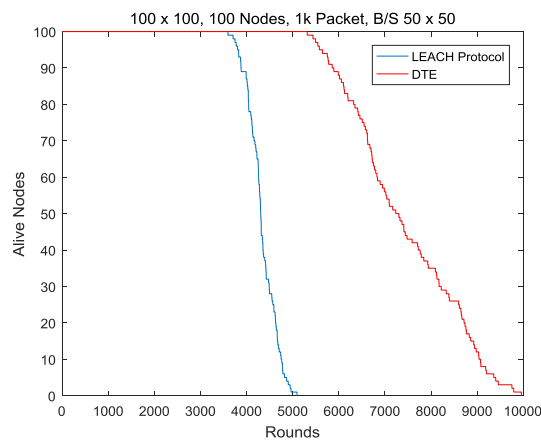

Figure 6. Network Lifetime Comparison of LEACH Protocol and DTE

In order to improve this, we propose a method to add a Single-hop layer for direct transmission within a certain range (d_0). The process of dividing the Sensor Field is shown in Fig. 7 and the procedure is as follows.
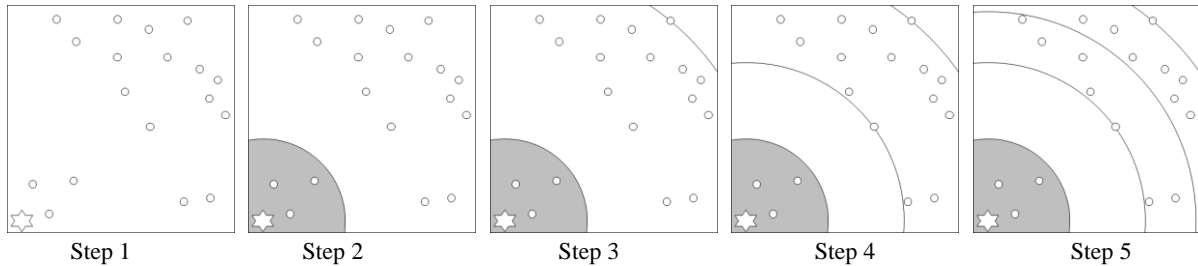
Step 1: Assume that the sensor nodes and the Base Station are in the Sensor Field as shown in Fig 7. In the figure, the star shape is the Base Station and the circle shape is the sensor node

Step 2: Divide the range from the Base Station to a certain range (d_0) into a Single-hop layer.

Step 3: Exclude the Single-hop layer and map the circular area based on the distance (d_{far}) to the node farthest from the Base Station.

Step 4: Exclude the Single-hop layer and map the circular area based on the distance (d_{near}) from the node closest to the Base Station.

Step 5: Map the circle area based on the middle point between d_{near} and d_{far}. The Sensor Field is divided into d_0, d_{near}, d_{far}, and $\frac{d_{near}+d_{far}}{2}$.

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 |

Figure 7. The process of dividing L-SEP Layer with Single-hop Layer

After dividing the layer as described above, a Cluster Head is selected for each layer except for the Single-hop layer, and a cluster is formed.

Similar to the conventional L-SEP, the Cluster Head of the outer layer transmits data to the Cluster Head of the inner layer. And the Cluster Head of the inner layer collects all the data. Next, data is transmitted to the Base Station according to the Single-hop layer transmission method. Table 1 below shows the proposed Single-hop layer transmission method.

Table 1. Proposed Method

	Proposal 1: Transmission without passing through Single-hop layer	Proposal 2: Transmission via Single-hop layer
Transmission method		

The first method of transmission is to transmit the inner layer directly to the Base Station without going through the Single-hop layer. And the second method of transmission is to transmit the inner layer to the Base Station via the Single-hop layer.

4. Simulation and Results

4.1. Simulation

In order to see how much better the proposed method than the existing protocol, a simulator is constructed with MATLAB. Table 2 shows the parameters for the simulation.
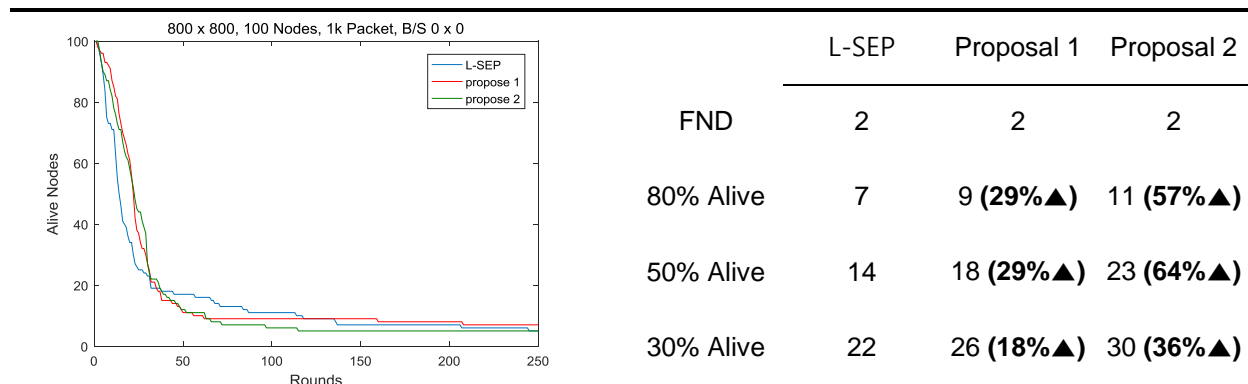
Table 2. Simulation Parameters

Parameters	Value	Parameters	Value
Data Aggregation	5nJ/bit/signal	Position of Base Station	0 x 0
Energy dissipation to run the radio device	50nJ/bit	Sensor Field	400 x 400, 800 x 800
Free space model of Transmitter Amplifier	10pJ/bit/m2	Initial Energy	0.5 J
Multi path model of Transmitter Amplifier	0.0013pJ/bit/m2	Advanced Node Additional Energy	3
		Ratio of Advanced Node	0.2 (20%)
		Number of Sensor Nodes	100

4.2. Simulation Results

Table 3 shows the simulation results when the Sensor Field is 800 x 800.

The proposed method is improved by up to 64% compared to the conventional L-SEP.

Table 3. Simulation Result when Field is 800 x 800

	L-SEP	Proposal 1	Proposal 2
FND	2	2	2
80% Alive	7	9 **(29%▲)**	11 **(57%▲)**
50% Alive	14	18 **(29%▲)**	23 **(64%▲)**
30% Alive	22	26 **(18%▲)**	30 **(36%▲)**

5. Conclusion

When the Sensor Field becomes wider, the proposed method has a performance improvement of 64% over the conventional method. This indicates that the larger the Sensor Field, the more efficient the proposed method is. From the experimental results, the proposed method is suitable for the wide Sensor Field.

In order to ensure that the protocol is always efficient, we propose a new protocol that uses more efficient one among the existing and proposed methods according to the node ratio of the Single-hop layer.

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