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Improvement of cluster head selection method in L-SEP

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Abstract

This paper deals with the improvement of cluster head selection method in L-SEP for heterogeneous nodes among hierarchical routing protocols of wireless sensor network. Wireless sensor networks are classified into homogeneous and heterogeneous network. In heterogeneous network, SEP, L-SEP are mainly used because cluster head selection probability is different depending on node type. But, since protocol based on SEP has different cluster head selection probabilities depending on the node type, clusters that transmit data inefficiently can be formed. to improve this, it is necessary to select the cluster head that minimizes the transmission distance of member node and the cluster head. Therefore, we propose a protocol that improve the cluster head selection method.

Keywords: *L-SEP, heterogeneous nodes, cluster head, cluster head selection probabilities*

1. Introduction

Recently, ubiquitous networks are attracting attention due to the development of wireless communication and electronics. wireless sensor networks [1-3] among core technologies of ubiquitous consists of many wireless sensor nodes. Unlike the wired networks, the wireless sensor networks have limited power to operate the network. Therefore, when designing a wireless sensor networks, it is important to use efficiently the limited power of the network by minimizing the energy consumption of each wireless nodes.

Wireless sensor networks are classified into homogeneous and heterogeneous network [4] depending on type of nodes with battery energy and functionality. A homogeneous sensor network consists of sensor nodes with identical in terms of battery energy and hardware complexity. On the other hand, in a heterogeneous sensor network, two or more different types of nodes with different battery energy and functionality are used. To minimize energy consumption, various routing protocols have been proposed for homogeneous network, and heterogeneous network. First, the LEACH protocol is mainly used in homogeneous network. The LEACH protocol selects cluster heads randomly using threshold [5]. And, nodes that is not a cluster head form a cluster with a closest cluster head. After cluster is formed, the member nodes transmit sensing data to a cluster head. The cluster head aggregates received data and transmits them to base station. Clustering can reduce the energy consumption rather than directly transmission. Unlike homogeneous networks, heterogeneous network consists of Normal nodes and advanced nodes with more battery than Normal nodes. SEP is basically a protocol for heterogeneous networks. SEP has operations like the LEACH protocol. But

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SEP has a problem that the more distance between cluster head and base station is longer, the more energy consumption is rapidly increased. L-SEP has been proposed to overcome the disadvantages of SEP. L-SEP is SEP protocol that adds Layer concept. And L-SEP selects the cluster head at each layer. By dividing the sensor field, L-SEP can reduce the transmission distance of cluster heads. But, when cluster is formed, the transmission distance of the member nodes and that of the cluster head may be significantly long depending on the placement of the advanced node, which is likely to become a cluster head. To improve this problem, after cluster is formed, on the assumption that each node of cluster is cluster head, we propose an algorithm to reduce the energy consumption by calculating expected consumption energy of cluster and reselecting the cluster head.

2. Related Researches

2.1 LEACH (Low Energy Adaptive Clustering Hierarchy) protocol

LEACH protocol is a clustering-based hierarchical routing protocol proposed by Wendi B. Heinzelman [6]. The process of clustering of LEACH protocol is shown in Figure 1.

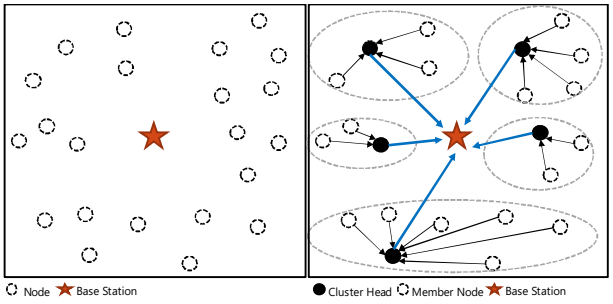


Figure 1. LEACH protocol

LEACH protocol is composed of a set-up phase and a steady-state. In the set-up phase, cluster heads are selected using Equation (1), and clusters are formed.

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

Base station compared with random number between 0 and 1 and T(n). if the random number is smaller than T(n), we select the Nth node as the cluster head. And then, nodes that is not a cluster head form a cluster with a closest cluster head. After cluster is formed, based on the number of nodes in the cluster, the cluster head creates a TDMA schedule telling each node when it can transmit. In the steady state phase, member nodes transmit sensing data to a cluster head. And each cluster heads aggregate received data and transmit them to the base station.

2.2 SEP (A Stable Election Protocol for clustered heterogeneous wireless sensor networks)

SEP is basically a protocol for heterogeneous network and gives a different cluster head probability equation depending on the type of nodes [7]. The process of clustering of SEP is shown in Figure 2.

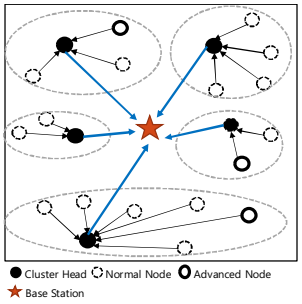


Figure 2. SEP

Unlike homogeneous network such as LEACH protocol, heterogeneous network consists of normal nodes and advanced nodes with more battery than normal node. SEP has operation like the LEACH protocol. but, when SEP selects cluster head, weight is applied to advanced node with higher energy to increase the selection probability. The cluster head selection probability normal node and advanced node are shown in Equation. (2).

$$T(s_{nrm}) = \begin{cases} \frac{P_{nrm}}{1-P_{nrm}\cdot\left(r \bmod \frac{1}{P_{nrm}}\right)}, & \text{if s} \in G' \\ 0, & \text{otherwise} \end{cases}, T(s_{adv}) = \begin{cases} \frac{P_{adv}}{1-P_{adv}\cdot\left(r \bmod \frac{1}{P_{adv}}\right)}, & \text{if s} \in G'' \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$T(s_{nrm})$ is the cluster head selection probability of the normal node and $T(s_{adv})$ is cluster head selection probability of the advanced node. But, SEP has a disadvantage that the more distance between cluster head and base station is longer, the more energy consumption is rapidly increased. To improve this, L-SEP has been proposed.

2.3 L-SEP (Layered-SEP)

L-SEP is basically a protocol based on SEP. L-SEP is SEP that adds Layer concept to reduce distance between cluster head and base station [8]. And the process of clustering of L-SEP is shown in Figure 3.

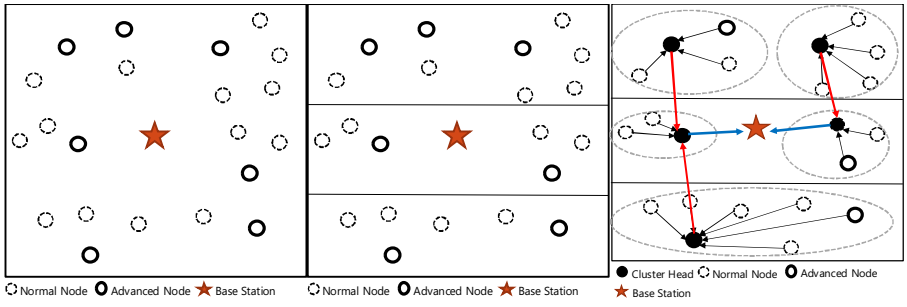


Figure 3. L-SEP

L-SEP divides the sensor field into a few layers. The layer in which are close to base station is called an inner layer, and the layer in which is a layer far from the base station is called outer layer [9,10]. After the layers are divided, a cluster head is selected for each layer and cluster is formed. clusters of outer layer transmit the data to clusters of inner layer. And the clusters of inner layer aggregate received data and transmit them to base station. By dividing the sensor field, L-SEP can reduce the distance between cluster head and base station. But, since advanced node preferentially selected as the cluster head, inefficient clusters can be constructed [11].

3. Proposed algorithm

3.1 Motivation

Protocol based on SEP is more likely to select the advanced node as cluster head. Therefore, when cluster is formed, the transmission distance of the member nodes and that of the cluster head may be significantly long depending on the placement of the advanced node, which is likely to become a cluster head. this mean that clusters that data is inefficiently transmitted may be formed. that is, Since the energy consumption of the node is proportional to square of distance or the four squares of distance, it is necessary to select the cluster head that minimizes the transmission distance of the member node and the cluster head.

3.2 Proposed algorithm

After cluster is formed, the more battery of cluster head is large, or transmission distance of member node is short, the more network efficiency is increased. To form cluster that consume less energy, we assume that each node in cluster is cluster head, and calculate the expected energy consumption of cluster. for example, when the configuration of the cluster is as shown in the below Figure, the procedure of the proposed protocol is as follows.

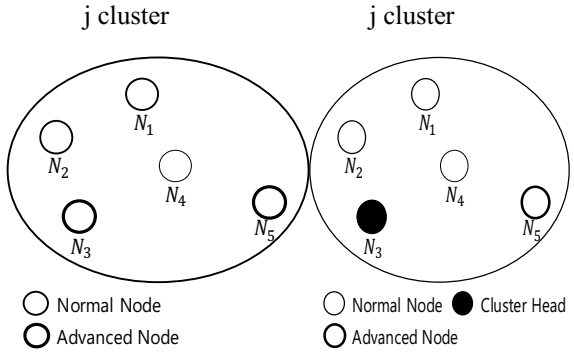
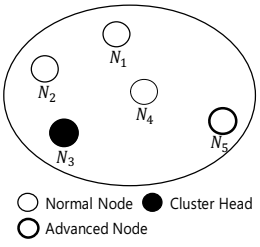


Figure 4. Configuration of cluster in L-SEP

Step 1: we find the residual energy of each node in cluster and sum of distances between nodes in cluster. Residual energy of each node in cluster and sum of distances between nodes is expressed by Equation (3).

$$\text{Residual energy of node in a cluster} = \mathrm{E_{res}(N_i)}$$
$$\text{Sum of distances between nodes}\left(\mathrm{SUM}\left(d_{toN_i}\right)\right) = \sum_{k=1}^{n_{C_j}} d_{N_i toN_k}\,(k \neq i) \quad (3)$$

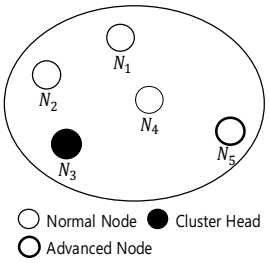
N_i means node number, n_{C_j} is number of node in the j cluster.



Node	Residual Energy	Sum of distances
N_1	2.0	432.18
N_2	0.5	324.44
N_3	0.5	522.14
N_4	2.0	429.33
N_5	0.5	345.65

Figure 5. Residual Energy and Sum of distances between nodes

Step 2: nodes are sorted in descending order based on residual energy and in ascending order based on sum of distances.

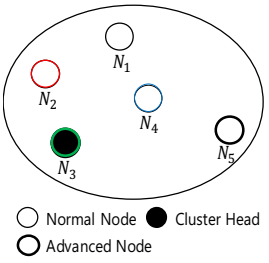


Node	Residual Energy	Sum of distances
N_1	2.0	432.18
N_4	2.0	429.33
N_3	0.5	522.14
N_2	0.5	324.44
N_5	0.5	345.65

Node	Residual Energy	Sum of distances
N_4	2.0	429.33
N_1	2.0	432.18
N_2	0.5	324.44
N_5	0.5	345.65
N_3	0.5	522.14

Figure 6. Sorting

Step 3: nodes that sum of the distances is the minimum among the same residual energy are included in S set. Also, cluster head is included in the S set. $(\{N_4, N_2, N_3\} \in S)$ The red box and the blue box represent member nodes, and the green box represents cluster head. By sorting and including some nodes in the S set, we can reduce the calculation process of the expected energy consumption of cluster.



Node	Residual Energy	Sum of distances
N_4	2.0	429.33
N_1	2.0	432.18
N_2	0.5	324.44
N_5	0.5	345.65
N_3	0.5	522.14

Figure 7. Including some nodes in S set

Step 4: when we assume that each nodes of S set is selected as the cluster head, we calculate the expected energy consumption of the cluster. Estimated energy consumption of cluster is as shown in Equation 4.

$$E_{C(j,\ i)} = E_{CH} + \sum_{k=1}^{n_{C_j}} E_{MN_k} (k \neq i) \quad if\ (N_i \in S) \tag{4}$$

C (x, y) means that the cluster head of x cluster is y. E_{CH} is the energy consumption of the cluster head, and E_{MN} is the energy consumption of the member node. Using the equation (4), we can obtain $E_{C(j,\ 2)}, E_{C(j,\ 3)}, E_{C(j,\ 4)}$ of the nodes belonging to S set in Figure 7

Step 5: the node with the lowest expected energy consumption of the cluster is reselected as the cluster head. Expected minimum energy consumption of the cluster is as shown in Equation 5.

$$\text{MIN}\ [E_{C(j,i)}]\ \ if\ (N_i \in S) \tag{5}$$

Using the equation (5), the minimum values of $E_{C(j,\ 2)}, E_{C(j,\ 3)}, E_{C(j,\ 4)}$ obtained in step 4 can be obtained. That is, the node N_i with the lowest expected energy consumption of the cluster obtained using the MIN

$[E_{C(j,\ 2)},\ E_{C(j,\ 3)},\ E_{C(j,\ 4)}]$ is re-selected as the cluster head.

4. Simulation and Result

4.1 Simulation

This paper simulates the performance of the proposed protocol by MATLAB. And we use Radio Model as a wireless propagation. The parameters for Simulation and that for Sensor field are shown in below Table. All simulations were performed 10 times to make sure the accuracy of each simulation and averaged the results.

Table 1. Simulation parameter

Parameters	Control Variables
Node initial energy	0.5J,2.0J
Message size	1000bit
E_{elec}	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4

Table 2. Sensor field parameter

Parameters	Control Variables
Field size (M)	400(m)*400(m)
Base station location	(200(m),200(m))
Number of sensor nodes (N)	100
Ratio of Advanced (m)	0.2 (20%)
Advanced Additional Energy (α)	3
Cluster selection probability (p)	0.1 (10%)

Sensor field size is 400 x 400. And the base station is placed in the center of sensor field. The additional energy of the Advanced node is three times the normal node, Ratio of Advanced is 0.2%. The number of layer is set to three and the cluster head selection probability of the sensor field is 0.1. When node placement of two protocol is the same, the cluster result of each protocol is as shown in the Figure 8.

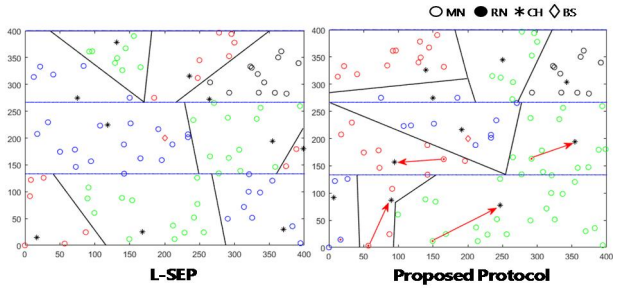


Figure 8. Sensor Field of L-SEP proposed protocol

In proposed protocol, red arrows indicate cluster head re-selection.

4.2 Result

We simulated two protocols to confirm energy consumption. Total energy consumption per round of the two protocols shows that energy consumption of clusters of proposed protocol is reduced rather than existing protocol. Figure 9 shows Total energy consumption per Round of L-SEP and proposed protocol.

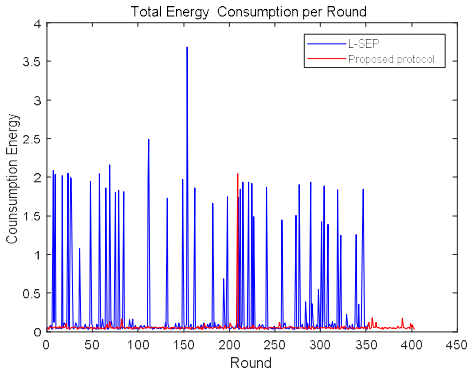


Figure 9. Total Energy consumption per Round of L-SEP and proposed protocol

When all nodes no die, average of total energy consumption per round of L-SEP is 0.273703 and the average of the proposed protocol is 0.056936. the average of the proposed protocol was reduced by 79% compared to the existing protocol.

Figure 10 shows the simulated results of alive node per round of L-SEP and proposed protocol. And Table 3 shows the simulated results of FND, Alive node 80%, Alive node 50%.

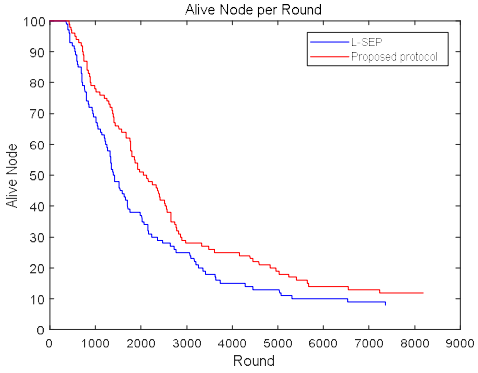


Figure 10. Alive node per Round of L-SEP and proposed protocol

Table 3. Simulation parameter

400x400	FND	Alive 80%	Alive 50%
L-SEP	360	711	1389
Proposed protocol	417(▲16%)	889(▲25%)	2051(▲48%)

FND means round that dead node is at least one. When the number of alive node is 50%, the proposed protocol improves up to 48%.

5. Conclusion

In this paper, we propose a new routing protocol that improve cluster head selection method. In order to prevent inefficient cluster is constructed by selecting cluster head depending on node type, we assume each node is cluster head in a cluster and calculate estimated energy consumption of cluster. And node having lowest estimated energy consumption of cluster is re-selected to cluster head.

Compared to the existing L-SEP, total energy consumption of proposed protocol is reduced, and network

life time of proposed protocol improves by more than 16% up to 48%. With all simulated results, the proposed protocol has more network lifetime and more stable than the L-SEP.

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