Journal of Engineering and Applied Sciences 13 (5): 1073-1077, 2018
ISSN: 1816-949X

Improved Method of Electing Cluster Head for L-SEP

[1]Seung Yeon Jin, [2]Kye-Dong Jung and [2]Jong-Yong Lee
[1]Department of Information System, Graduate School of Information Contents,
Kwang Woon University, Seoul, Korea
[2]Ingenium College of Liberal Arts, Kwang Woon University, Seoul, Korea

Abstract: This study handles the improvement of cluster head election method in L-SEP for heterogeneous protocol among hierarchical routing protocols of wireless sensor network. Wireless sensor networks can be broadly categorized into two types like homogeneous network and heterogeneous network. Heterogeneous network constitutes nodes of different types. Among them, SEP and L-SEP are mainly used in networks where the initial energy constitutes other nodes. protocols based on SEP have different cluster head election probabilities depending on initial energy. However, it means that the cluster head may be elected depending on the node type, so that, a cluster which transmits data inefficiently may be configured. to improve this, it is necessary to elect the cluster head that minimizes estimated energy consumption of cluster. Therefore, we propose a method for re-election of the cluster head with the smallest energy consumption of the cluster.

Key words: L-SEP, heterogeneous nodes, cluster head, estimated energy consumption of cluster, network, constitutes

INTRODUCTION

Wireless sensor networks among the core technologies of ubiquitous network are composed of many wireless sensor nodes. Unlike wired networks, wireless sensor networks use limited power to operate the network. Therefore when designing wireless sensor networks, it is important to minimize the energy consumption of each wireless node and efficiently use the limited power of the network (Akyildiz *et al*., 2002; Chong and Kumar, 2003; Singh and Sharma, 2014; Smaragdakis *et al*., 2004).

Wireless sensor networks are classified into homogeneous and heterogeneous networks depending on node type (Mhatre and Rosenberg, 2004) A homogeneous sensor network consists of the same sensor nodes in terms of battery energy and hardware complexity. On the other hand, heterogeneous sensor networks use two or more different types of nodes with different battery energies and functions. Various routing protocols have been proposed for homogeneous and heterogeneous networks to minimize energy consumption. First, the LEACH protocol is mainly used in homogeneous networks. The LEACH protocol uses the threshold to randomly elect the cluster head (Lee, 2015). And non-cluster heads form a cluster with the closest cluster head. After the cluster is formed, the member node sends the sensing data to the cluster head. The cluster head aggregates the received data and sends it to the base station. Clustering can reduce energy consumption rather than direct transmission. Unlike a homogeneous network, a heterogeneous network consists of normal nodes and more advanced nodes with more battery than normal nodes. SEP is basically a protocol for heterogeneous networks. SEP has operations such as the LEACH protocol. However, SEP has a problem that the energy consumption increases sharply as the distance between the cluster head and the base station increases. L-SEP is proposed to solve the cluster head transmission distance problem of SEP. L-SEP is a SEP that adds layer concept. L-SEP then elects cluster heads in each layer. By dividing the sensor field, the L-SEP can reduce the transmission distance of the cluster head. However when a cluster is formed, the distances of the member nodes and the cluster heads can become quite long, depending on the placement of the advanced nodes which are likely to be cluster head. To improve this, we propose an algorithm to reduce the energy consumption by computing the estimated energy consumption of the cluster and reelecting the cluster head.

Literature review

LEACH (Low Energy Adaptive Clustering Hierarchy) protocol: LEACH protocol is a clustering-based hierarchical routing protocol proposed by Heinzelman *et al*. (2000). Clustering process of LEACH protocol is shown in Fig. 1.

Corresponding Author: Jong-Yong Lee, Ingenium College of Liberal Arts, Kwang Woon University, Seoul, Korea

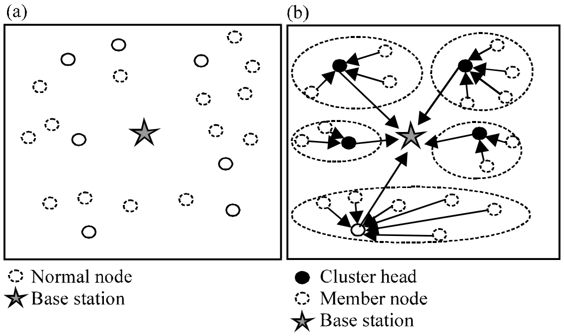

Fig. 1: a, b) Clustering process of LEACH

The LEACH protocol consists of a set-up phase and a steady-state. In the setup phase, the cluster head is elected using Eq. 1 and a cluster is formed:

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

The base station is compared with a random number between 0 and 1 and T(n). When the random number is smaller than T(n), the Nth node is elected as the cluster head. Then the non-cluster head node forms a cluster with the closest cluster head. When a cluster is formed, based on the number of nodes in the cluster, the cluster head creates a TDMA schedule that informs each node when it can transmit. In the steady-state phase, the member node sends sensing data to the cluster head. Each cluster aggregates the received data and sends it to the base station.

SEP; A Stable Election Protocol for clustered heterogeneous wireless sensor networks: SEP is basically a protocol for heterogeneous network and provides different cluster head probability equations depending on the type of node (Smaragdakis *et al*., 2004). The clustering process for SEP is shown in Fig. 2.

Unlike homogeneous network, heterogeneous network is comprised of normal nodes and advanced nodes with more initial energy than normal nodes. SEP has the same behavior as the LEACH protocol. When the SEP elects the cluster head, the cluster head election probability of the advanced node with the higher initial energy is higher. The cluster head election probability of normal nodes and advanced nodes are as Eq. 2:

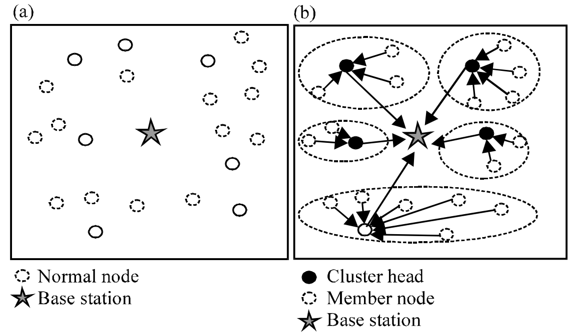

Fig. 2: a, b) Clustering process of SEP

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

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

Where:

$T(S_{nrm})$ = The cluster head election probability of the normal node

$T(S_{adv})$ = Cluster head election probability of the advanced node

But, the SEP increases the energy consumption as the distance between the cluster head and the base station increases. To improve this, L-SEP has been proposed.

L-SEP; Layered-SEP: L-SEP can reduce the distance between cluster head and base station by adding layer concept (WooSuk *et al*., 2017a, b). The clustering process for L-SEP is shown in Fig. 3.

L-SEP divides sensor field into layers of constant size. The layer closest to the base station is called the inner layer and the layer far from the base station is called the outer layer. After the layers are split, the cluster head is elected for each layer and the cluster is formed. Clusters in the outer layer send data to clusters in the inner layer (Song *et al*., 2014; Singh and Mishra, 2015). The clusters in the inner layer aggregate the data received from the clusters in the outer layer and send them to the base station along with itself data. L-SEP can reduce the distance between the cluster head and the base station by dividing the sensor field. However, inefficient clusters can be constructed because advanced nodes are first elected as cluster heads.

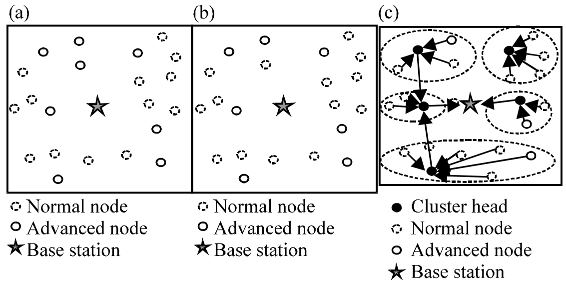

Fig. 3: a-c) Clustering process of L-SEP

MATERIALS AND METHODS

Proposed algorithm

Motivation: The protocol based on SEP preferentially elects the advanced node with higher initial energy as cluster head. Therefore when the cluster is formed, the transmission distance between the member node and the cluster head can be considerably long depending on the location of the advanced node. This means that clusters can be formed in which data is transmitted inefficiently. Therefore, since, the energy consumption of the node is proportional to the square of the distance or the quartic of the distance, the cluster head that minimizes the transmission distance of the member node and the cluster head should be elected.

Proposed algorithm: Therefore, to minimize the energy consumption of the cluster, we assume all nodes in the cluster are cluster heads, calculate the expected energy consumption. For example, when the cluster is formed as shown below, the procedure of the proposed protocol is as shown in Fig. 4.

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 Eq. 3:

$$\begin{aligned}&\text{Residual energy of node in a cluster} = E_{res}(N_i)\\&\text{Sum of distances between nodes}\left(\text{Sum}\left(d_{toN_i}\right)\right)=\\&\textstyle\sum_{k=1}^{n_{cj}} d_{N_i toN_k}\,(K\neq i)\ N_i \text{ means node number,}\\&n_{cj} \text{ is number of node in the cluster j}\end{aligned} \quad (3)$$

For example, we assume that the placement of nodes is as shown in Fig. 5. And we also assume that data of nodes-residual energy, sum of distances are as shown in Table 1. That is, the data of the nodes is expressed as following by Eq. 3.

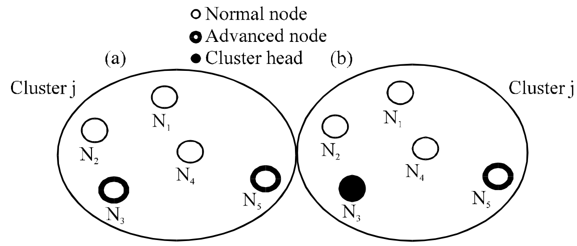

Fig. 4: Configuration of cluster in L-SEP

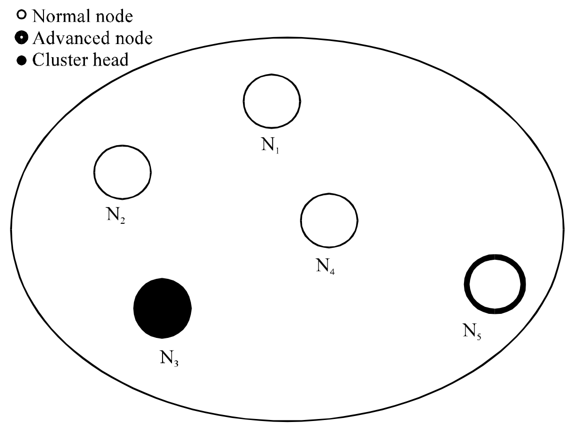

Fig. 5: Placement of nodes

Table 1: Residual energy and sum of distances between nodes

Nodes	Residual energy (J)	Sum of distances (m)
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

$$\begin{aligned}&E_{res}(N_1) = 2.0, E_{res}(N_2) = 0.5, E_{res}\\&(N_3) = 0.2, E_{res}(N_5) = 0.5\\&\left(\text{Sum}\left(d_{toN_1}\right)\right) = 432.18, \left(\text{SUM}\left(d_{toN_2}\right)\right) = 324.44\\&\left(\text{Sum}\left(d_{toN_3}\right)\right) = 522.14, \left(\text{SUM}\left(d_{toN_4}\right)\right)\\&= \left(\text{Sum}\left(d_{toN_5}\right)\right) = 345.65\end{aligned}$$

Step 2: Nodes in Table 1 are sorted in descending order based on residual energy, this result is shown in Table 2. then, nodes are sorted in ascending order based on sum of distance. The result is shown in Table 3. Residual energy takes precedence over sum of distances.

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. Therefore, the member nodes, both N_4 and N_2 are included in the S set. And the cluster head, N_3 also is included in S set.

Step 4: Assuming that the nodes in the S set are cluster heads, calculate the expected energy consumption of the cluster. The expected energy consumption of the cluster is as Eq. 4:

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

Where:

C (x, y) = The cluster head of cluster x is y
E_{CH} = The energy consumption of the cluster head
E_{MN} = The energy consumption of the member node

Using Eq. 4, we can obtain $E_{c(j,\ 2)}$, $E_{c(j,\ 3)}$ of the nodes belonging to S set in Fig. 6.

Step 5: The node with the lowest expected energy consumption of the cluster is re-elected as the cluster head. Expected minimum energy consumption of the cluster is as shown in Eq. 5:

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

Using Eq. 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-elected as the cluster head.

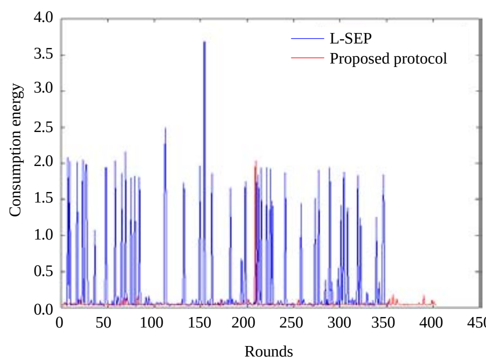

Fig. 6: Total energy consumption per round of L-SEP and proposed protocol

Table 2: Nodes sorted in descending order based on residual energy

Nodes	Residual energy (J)	Sum of distances (m)
N_1	2.0	432.18
N_2	2.0	429.33
N_3	0.5	522.14
N_4	0.5	324.44
N_5	0.5	345.65

Table 3: Nodes sorted in ascending order based on sum of distances

Nodes	Residual energy (J)	Sum of distances (m)
N_1	2.0	429.33
N_2	2.0	432.18
N_3	0.5	324.44
N_4	0.5	345.65
N_5	0.5	522.14

RESULTS AND DISCUSSION

Simulation: This study simulates the performance of the protocol proposed by MATLAB. It also uses the radio model. The parameters of the simulation and sensor fields are shown in Table 4 and 5. All simulations were performed ten times to verify the accuracy of each simulation and to average the results.

The sensor field size is 400×400. The base station is centered on the sensor field. The additional energy of the advanced node is three times the normal node and the advanced of ratio is 0.2%. The number of layers is set to 3 and the probability of cluster head election in the sensor field is 0.1. When both nodes have the same node placement, the cluster results for each protocol are shown in Fig. 7. In proposed protocol, red arrows indicate cluster head re-election.

We simulated two protocols to verify energy consumption. The total energy consumption per round of both protocols shows that the proposed protocol clusters have lower energy consumption than the existing protocols. Figure 7 shows the total energy consumption of the L-SEP and the proposed protocol per round.

When all nodes are not dead, the average 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 is 79% lower than the existing protocol.

Figure 8 shows the simulation results of L-SEP and alive node per round of the proposed protocol. Table 6 shows the simulation results for FND, 80% of alive nodes and 50% of alive nodes.

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%.

Table 4: Simulation parameter

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

Table 5: Sensor field parameter

Parameters	Control variables
Field size (M)	400×400 m
Base station location	200×200 m
Number of sensor nodes (N)	50 nJ/bit
Ratio of advanced (m)	0.2 (20%)
Advanced additional energy (α)	3
Cluster election probability (p)	0.1 (10%)

Table 6: Life time of L-SEP and proposed protocol

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

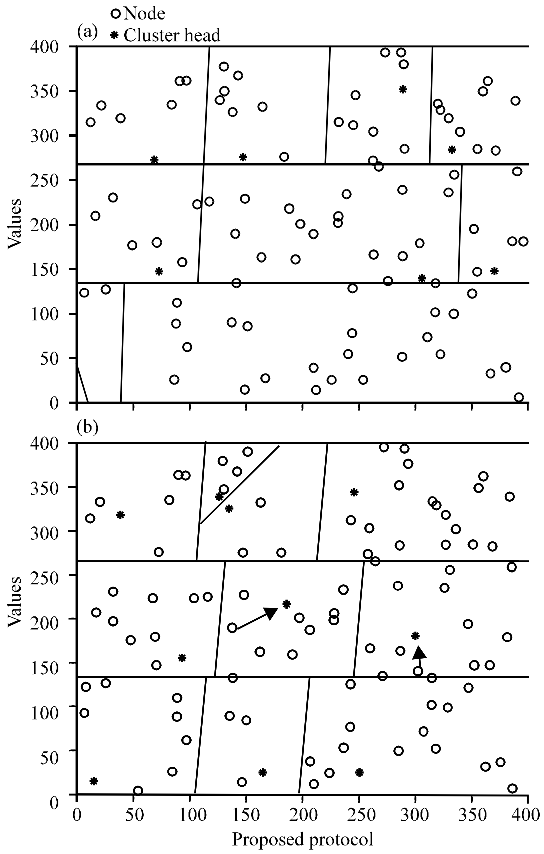

Fig. 7: a) Sensor field of L-SEP and b) Proposed protocol

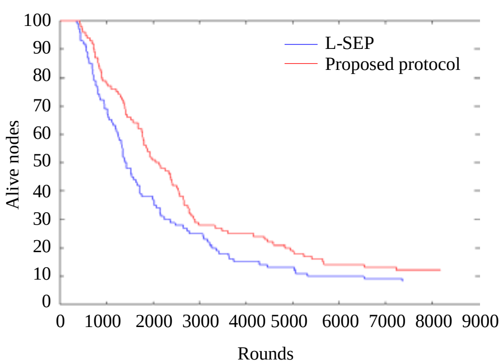

Fig. 8: Alive node per round of L-SEP and proposed protocol

CONCLUSION

In this study, we propose a new routing protocol to improve the cluster head election method. To prevent inefficient clusters from being configured by electing cluster heads based on node type, assume that each node is the cluster head of the cluster and calculate the expected energy consumption of the cluster. And the node with the least expected energy consumption of the cluster is elected again as the cluster head. Compared to the existing L-SEP, the total energy consumption of the proposed protocol is reduced and the network lifetime of the proposed protocol is improved by up to 16% and up to 48%. Simulation results show that the proposed protocol has more network life and stability than L-SEP.

REFERENCES

Akyildiz, I.F., W. Su, Y. Sankarasubramaniam and E. Cayirci, 2002. A survey on sensor networks. IEEE Commun. Mag., 40: 102-114.

Chong, C.Y. and S.P. Kumar, 2003. Sensor networks: Evolution, opportunities and challenges. Proc. IEEE., 91: 1247-1256.

Heinzelman, W.R., A. Chandrakasan and H. Balakrishnan, 2000. Energy-efficient communication protocol for wireless microsensor networks. Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, January 7, 2000, IEEE, New York, USA., ISBN:0-7695-0493-0, pp: 1-10.

Lee, J.Y., 2015. Energy improvement of WSN using the stochastic cluster head selection. J. Inst. Internet Broadcast. Commun., 15: 125-129.

Mhatre, V. and C. Rosenberg, 2004. Homogeneous vs heterogeneous clustered sensor networks: A comparative study. Proceedings of the 2004 IEEE International Conference on Communications Vol. 6, June 20-24, 2004, IEEE, Paris, France, pp: 3646-3651.

Singh, J. and A.K. Mishra, 2015. Clustering algorithms for wireless sensor networks: A review. Proceedings of the 2nd International Conference on Computing for Sustainable Global Development (INDIACom'15), March 11-13, 2015, IEEE, New Delhi, India, ISBN:978-9-3805-4415-1, pp: 637-642.

Singh, S.P. and S.C. Sharma, 2014. Cluster based routing algorithms for wireless sensor networks. Int. J. Eng. Technol. Innovations, 1: 1-8.

Smaragdakis, G., I. Matta and A. Bestavros, 2004. SEP: A stable election protocol for clustered heterogeneous wireless sensor networks'. Proceedings of the International Workshop on Sensor and Actor Network Protocols and Applications, May 31-31, 2004, Boston University, Boston, Massachusetts, pp: 251-261.

Song, Y.I., J.S. Lee, K.D. Jung and J.Y. Lee, 2014. Energy efficiency hierarchical multi-hop routing protocol for wireless sensor network. Adv. Appl. Converg. Adv. Cult. Technol., 1: 148-148.

WooSuk, L.E.E., K.D. Jung and J.Y. Lee, 2017a. EL-SEP: Improved L-SEP by adding single hop layer. Intl. J. Adv. Smart Convergence, 6: 50-56.

WooSuk, L.E.E., S.Y. Jin, K.D. Jung and J.Y. Lee, 2017b. Improving hot spot problem in layer of DL-LEACH. Intl. J. Internet Broadcast. Commun., 9: 64-69.