Improved Transmission of Cluster Head in LEACH Protocol

[1]Woo Suk LEE, [2]Kye-Dong Jung and [2]Jong-Yong Lee
[1]Department of Plasma Bioscience and Display,
[2]Ingenium College of Liberal Arts, Kwangwoon University, Seoul, Korea

Abstract: Wireless sensor network is a wirelessly configured network of sensor nodes with limited power such as batteries. If the sensor node's battery is exhausted, the node is no longer available. Therefore, if the network is to be used for a long time, energy consumption should be minimized. There are many wireless sensor network protocols. To improve energy efficiency, including cluster-based and chain-based protocols. Cluster-based protocols elect cluster heads and divide sensor field into clusters. The cluster head collects the data in the cluster and transmits it to the base station. In the case of nodes elected as cluster heads, there is a problem of energy consumption. The chain-based protocol links sensor nodes in a chain and finally transmits all data to the base station. In this study, we intend to increase the network lifetime by using a chain to reduce the energy consumption of the cluster head in the cluster-based protocol, LEACH protocol.

Key words: Chain, cluster, LEACH protocol, transmission distance, energy, time

INTRODUCTION

A wireless sensor network is a network in which sensor nodes capable of collecting data are composed wirelessly. Sensor nodes can be installed in a home, a natural environment, a road, etc. to measure or observe changes in the environment (Akyildiz *et al.*, 2002). Wireless sensor networks have these advantages but they also have drawbacks. Unlike a wired network, a wireless sensor network operates with a limited power source such as a battery for each sensor node. If the battery is exhausted, the sensor node will no longer function. Therefore, energy consumption should be minimized if the network is to be used for a long time. There are many wireless sensor network protocols to increase the energy efficiency of the network (Lee *et al.*, 2014). The LEACH protocol (Heinzelman *et al.*, 2000) is a cluster-based protocol that divides the sensor field into clusters which reduces the transmission distance of the member nodes in the cluster rather than directly to the base station. Also, all the nodes can be elected as the cluster head once by using the cluster head election threshold equation. PEGASIS (Lindsey *et al.*, 2000) is a chain-based protocol that uses sensor nodes to construct sensor chains using a greedy algorithm. One of the nodes constituting the chain becomes the leader node and transmits data to the base station. In the case of the LEACH protocol, the energy consumption of the cluster head is high. By improving the transmission method of the cluster head, the network lifetime can be improved.

In this study, we try to improve the network lifetime by constructing the cluster head nodes of the LEACH protocol as a chain and transmitting to the base station.

Literature review

Radio model: When data is transmitted from the sensor node, it requires transmission energy $E_{TX\text{-}elec}$ (1) and amplification energy $E_{TX\text{-}amp}$ (1, d) depending on the distance. When receiving data from a sensor node, it requires receiving energy $E_{RX\text{-}elec}$ (1). The flowchart of the radio model is shown in Fig. 1. Energy consumption is proportional to the square of the distance if the transmission distance is within the free space distance and energy consumption is proportional to the fourth power of the transmission distance when the transmission distance is outside the free space. The free space range was defined as d_0. Therefore, in a wireless network, energy consumption increases as the transmission distance increases. This is shown in Eq. 1. 1 is the data packet size and d is the transmission distance:

$$E_{TX}(1,d) = E_{TX\text{-}elec}(1) + E_{TX\text{-}amp}(1,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 \leq d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4 > d_0 \end{cases}$$

$$(1)$$

When receiving data, it requires receiving energy according to the size of the data message. The energy equation required at this time is shown in Eq. 2:
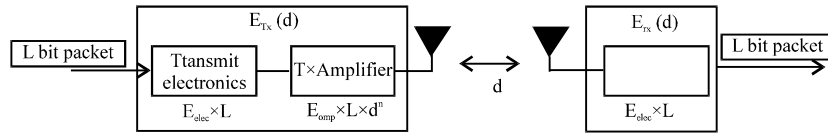

Corresponding Author: Jong-Yong Lee, Ingenium College of Liberal Arts, Kwangwoon University, Seoul, Korea

Fig. 1: Flowchart of radio model

$$E_{RX}(1) = E_{RX-elec}(1) = lE_{elec} \qquad (2)$$

LEACH protocol: The LEACH protocol is a cluster-based routing protocol. The sensor field is divided into clusters and there is one cluster head node per cluster. The LEACH protocol stochastically elects the cluster head and gives all the nodes in the cluster the opportunity to be elected as the cluster head. The LEACH protocol has a set-up phase in which cluster head elections are made and a steady-state phase in which transmission is actually effected. The cluster head consumes a lot of energy because it collects the data of the member nodes in the cluster and transmits it to the base station. When a node is continuously elected as a cluster head, the energy of the node is consumed immediately. Therefore, all nodes can be elected as a cluster head by using the threshold equation in the LEACH protocol. In the set-up phase, the cluster head is elected using the following eq. 3:

$$T(n) = \begin{cases} \dfrac{p}{1-p\left(r \bmod \dfrac{1}{2}\right)} & \text{if } n \in \\ 0 & \text{otherwise} \end{cases} \qquad (3)$$

In Eq. 3, r is the current round. If the set G is empty and there are no more nodes that can become cluster heads, put all remaining energy nodes in the set G, so that, they become cluster heads. Set G is the set to which nodes that are not elected to the cluster head belong. If the random number is less than the threshold T(n), the node is elected as the cluster head in the current round. Once all the cluster heads are elected, the member nodes in the cluster transmit the data to the cluster head. The cluster head transmits the data of the received member nodes and its own data to the base station.

PEGASIS: PEGASIS is a chain-based routing protocol. From the node farthest from the base station to the node closest to the base station, a greedy algorithm is used to construct a chain as shown in Fig. 2. Each node receives data from a nearby node and then transmits the data to another nearby node after data fusion. Finally, the node selected as the leader node among the nodes constituting the chain transmits data to the base station.
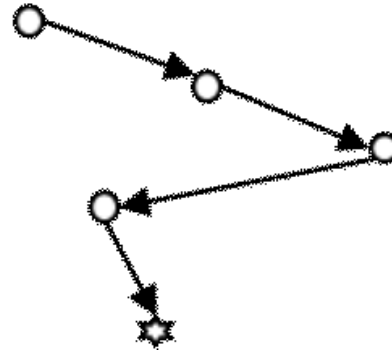

Fig. 2: Chain construction using the greedy algorithm

MATERIALS AND METHODS

In the case of the LEACH protocol, the transmission energy of the node is reduced by configuring the cluster. The cluster head that collects and transmits all the data in the cluster consumes more energy. When the sensor space is wide, the energy consumption of the cluster head is increased. In order to solve this problem, the cluster head nodes are configured as a chain and finally transmitted to the base station. The proposed method constructs clusters in the same way as existing LEACH protocol. Thereafter, the cluster head node does not transmit directly to the Base Station but forms a chain as in the following steps:

- Connect nodes in the range d_0 from the Base Station to the first chain. If there is no node in d_0 range, connect the nearest node
- Chain the nodes in the range d_0 with respect to the connected nodes. Similarly, if there is no node in the range, connect the closest node
  Repeat step 2 until all the nodes are in chain connection.

The chain configuration is proceeded as shown in Fig. 3. The cluster head transmits according to the configured chain.

This method can prevent the chain from circulating without using greedy algorithms. And one node can connect multiple chains, so that, it is possible to minimize the case of rotating outward from the farthest node to the destination like PEGASIS.
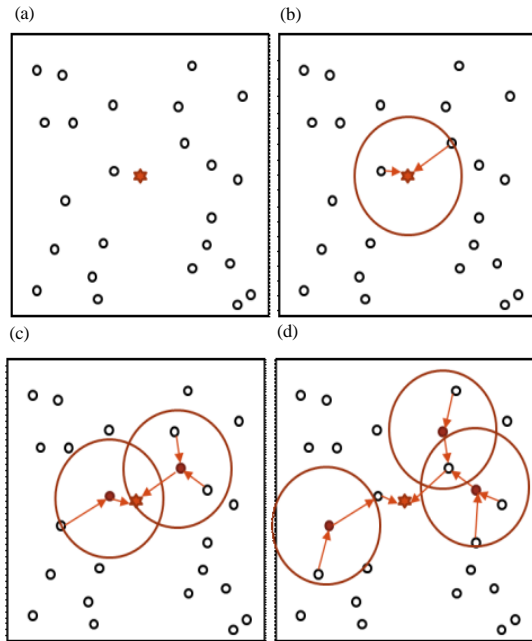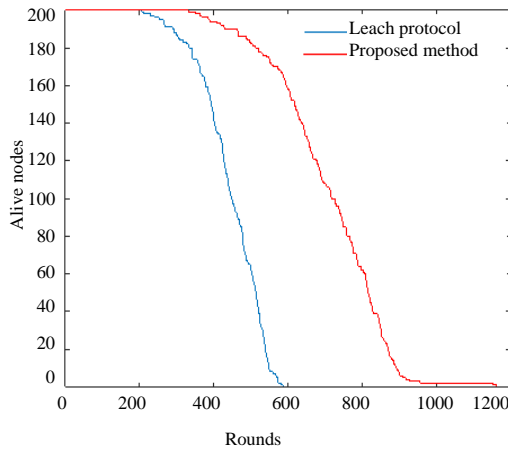
Fig. 3: a-d) Step of proposed method

Fig. 4: Simulation result

Table 1: Parameters of radio model

Parameters	Values
Data aggregation (E_{DA})	5 nJ/bit/signal
Energy dissipation to run the radio device (E_{elec})	50 nJ/bit
Free space model of Transmitter Amplifier (ε_{fs})	10 pJ/bit/m^2
Multi path model of Transmitter Amplifier (ε_{mp})	0.0013 pJ/bit/m^2

Table 2: Parameters of simulation

Parameters	Values
No. of sensor nodes (N)	200
Sensor field (M)	400×400
Position of base station	Center
Initial energy (e_0)	0.5 J
Packet size	2000 bit

Table 3: Simulation result

Parameters	FND	Improved ratio
LEACH protocol	206	-
Proposed method	331	60% ▲

CONCLUSION

The clustering-based wireless sensor network protocol is useful for improving the network lifetime but the cluster head node consumes a large amount of energy because the cluster data is collected and transmitted to the base station. In addition when the sensor field is wide, the transmission distance of the cluster head may increase, thereby consuming a large amount of energy. In order to improve this, a cluster head node is configured to be a chain, so that, the cluster head node can be routed through the nearest cluster head node without being directly transmitted to the base station. Simulation results show that in a wide sensor field, the network lifetime is better than the existing LEACH protocol.

RESULTS AND DISCUSSION

We compared the network lifetime of the proposed method and the existing LEACH protocol. The radio model parameters and simulation parameters are shown in Table 1 and 2 and the nodes are randomly arranged.

Figure 4 and Table 3 show the results of network lifetime comparison using the above simulation parameters.

Simulation results show that the proposed method improves the network lifetime by 60% compared to the existing LEACH protocol based on FND.

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