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Improved Energy Consumption of LEACH Protocol Through Inner-Cluster Multi-hop

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Abstract: This study proposes inner cluster multi-hop transmission to improve the energy consumption efficiency of the LEACH protocol. Since the LEACH protocol randomly selects cluster heads by threshold stochastic and forms any clusters, there may be a member node whose transmission distance is longer than the distance threshold value. If the transmission distance of any member node is longer than the distance threshold value, this member node quickly consumes energy. Therefore, we considered inner-cluster multi-hop transmission to reduce the transmission distance of these member nodes. And this study has derived the minimum threshold distance for efficient multi-hop transmission. In addition, we have let the member node determine the Hop number according to the minimum threshold distance. As a result, when the inner cluster multi-hop transmission is applied to the LEACH protocol, the energy efficiency is improved as the density of the node becomes smaller.

Key words: Inner cluster multi-hop, LEACH protocol, distance threshold value, minimum threshold distance, energy, efficiency

INTRODUCTION

Wireless Sensor Network (WSN) is the core technology of ubiquitous network. In general, a wireless sensor network consists of a number of sensor nodes with sensing capabilities. These wireless sensor nodes have physical limitations such as limited battery, processing power and communication distance. For example, it is difficult to replace or recharge the node's batteries because the wireless sensor nodes are often placed in places that are difficult for human access. Therefore, it is important to minimize the energy consumption of each node and maximize the energy efficiency of the network in order to efficiently use the limited battery of the nodes of the wireless sensor network (Akyildiz *at al*., 2002) also, various routing protocols have been proposed for efficient operation of sensor nodes. A representative routing protocol is the clustering-based LEACH protocol. The LEACH protocol is a clustering-based protocol and consists of two stages: setup phase and a steady state. In the setup phase, the LEACH protocol selects a cluster head using a stochastic threshold and forms a cluster. Each cluster consists of one cluster head and several member nodes. In the steady state, the member nodes in the cluster transmit data to the cluster head. The cluster head transmits the data to the base station by aggregating. Clustering of the LEACH protocol has the advantage of increasing network efficiency by dispersing the energy consumption of all nodes. However, since, the cluster is arbitrarily formed in the LEACH protocol, there is a problem that when the member node transmits data to the cluster head, the transmission distance of the member node may be longer than the distance threshold value. If the transmission distance of the node is longer than the distance threshold value, it is necessary to reduce the transmission distance of the member node because the energy of this member node is consumed quickly. Therefore, this study considers inner cluster multi-hop transmission to reduce the transmission distance of the member node as much as possible. And we derive the minimum threshold distance for efficient multi-hop transmission. Furthermore, we have let the member node determine the hop number according to the minimum threshold distance.

Literature review

Sensor network clustering: Cluster-based protocols generally involve the process of dividing the sensor space into multiple clusters. This is called clustering. By dividing the sensor field into clusters through clustering, the data and the number of transmissions of the node can be reduced (Mahajan and Pushpender, 2016). A cluster

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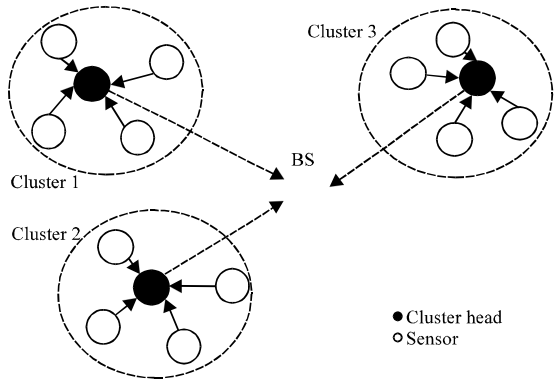

Fig. 1: Structure of cluster

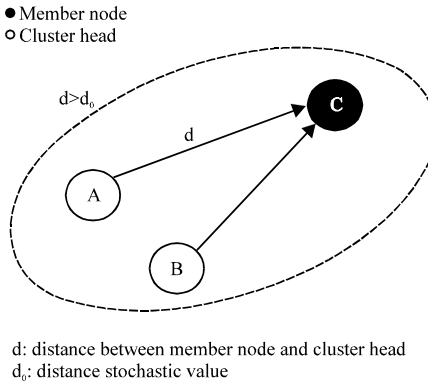

Fig. 2: Structure of LEACH protocol

consists of one cluster head and several member nodes. Member nodes in the cluster transmit data to the cluster head. Then, the cluster head that receives the data transmits the data to the base station by aggregating. Figure 1 shows the structure of the cluster.

As shown in Fig. 1, clustering can reduce energy waste due to data redundancy of nodes. However, this means that a particular node can be continuously selected to the cluster head (Lee *et al*., 2014). To solve this problem, the LEACH protocol which is a clustering-based protocol has been proposed.

LEACH protocol: The LEACH protocol is a representative clustering-based protocol proposed by Heinzelman *et al*. (2000). The LEACH protocol consists largely of a set-up phase and a steady-state phase. In the set-up phase, the cluster head is selected by the stochastic threshold. Then, the selected cluster head forms a cluster with surrounding sensor nodes. The cluster head informs the member nodes of a Time Division Multiple Access (TDMA) schedule. In the steady state, the member nodes in the cluster transmit data to the cluster head based on the TDMA schedule. And the cluster head processes the received data and myself data by aggregating. The cluster head directly transmits to the base station by a CDMA (Code Division Multiple Access) method. Figure 2 shows the structure of the LEACH protocol.

The LEACH protocol has the advantage of distributing the energy consumption of the network by selecting all the nodes as cluster head once. However, since the LEACH protocol randomly selects the cluster head by the stochastic threshold, there is a problem that the distance between the member node and the cluster head may become long (Jin *et al.*, 2017).

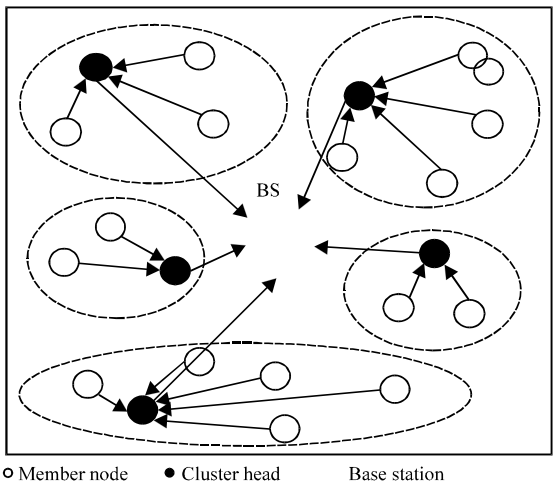

Fig. 3: Arbitrary cluster in LEACH protocol

Problem: The LEACH protocol randomly selects a cluster head by stochastic threshold. As a result, an arbitrary cluster can be formed as shown in Fig. 3. If the distance (d) between the member node A and the cluster head C is longer than the distance threshold value (d_0), the energy of the member node A is consumed quickly. The energy consumption of the node is proportional to d^2 or d^4 based on the distance threshold value (d_0).

Proposed: In this study, we consider inner cluster multi-hop to reduce the transmission distance of member nodes. And derives a minimum threshold distance (d_{th}) for efficient multi-hop transmission (Kumar *et al*. (2010). Also, the number of hop of the member node according to minimum threshold distance (d_{th}) is determined.

It is assumed that the distance between the member node and the cluster head is d, energy required for amplification in free space is ε_{fs}(10pJ/bit/m^2), energy

Table 1: Efficient transmission method

Distance range	Efficient transmission method
$d_0(87.7058)<d<d_{th\_2hop}(104.412)$	Direct transmission
$d_0(104.412)\leq d<d_{th\_2hop}(124.0928)$	2-hop transmission
$d_{th\_2hop}(124.0928)\leq d$	3-hop transmission

required for amplification in multi-path is $\varepsilon_{mp}(0.0013pJ/bit/m^4)$, distance threshold value is $d_0(\varepsilon_{fs}/\varepsilon_{mp}$, around 87.7 m), the minimum threshold distance for the multi-hop transmission is d_{th}. And we compare the amount of energy consumed in direct transmission with the amount of energy consumed in multi-hop transmission. By using this, minimum threshold distance that multi-hop transmission is always efficient can be obtained. Therefore, the efficient transmission method of the member node according to the distance (d) between the member node and the cluster head is shown in the following Table 1.

RESULTS AND DISCUSSION

Table 2 and 3 show the simulation environment when the routing algorithm proposed in the optimal cluster number environment of the LEACH protocol is applied. We used MATLAB to verify the proposed routing technique.

Table 2: Simulation parameter

Simulation parameter	Values
Sensor field size	400×400
Base station location	50 and100 (m)
Position of base station	(200, 200)
Initial energy (B_0)	0.5 (J)
Number of sensor node	50, 100, 200

Table 3: Cluster head election probability

Number of sensor node	Cluster head election probability
50	0.14
100	0.13
200	0.09

Table 4: Comparison according to the number of multiple hops in the cluster of LEACH protocol

Transmission method	Node 200	Node 300	Node 400
Direct transmission	374	263	216
2-hop transmission	376 (▲0.5%)	271 (▲3%)	233 (▲8%)
3-hop transmission	376 (▲0.5%)	277 (▲5%)	240 (▲11%)

The sensor field environment of the LEACH protocol using the proposed routing scheme when the number of nodes is 200, 100 and 50 is shown in Fig. 4. The arrow shows the Multi-hop transmission in Fig. 4. That is, as the density of nodes decreases, the distance between nodes increases and the number of 2-hop transmission or 3-hop transmission increases. Table 4 compares the FND of the LEACH protocol with the LEACH protocol using inner cluster multi hop.

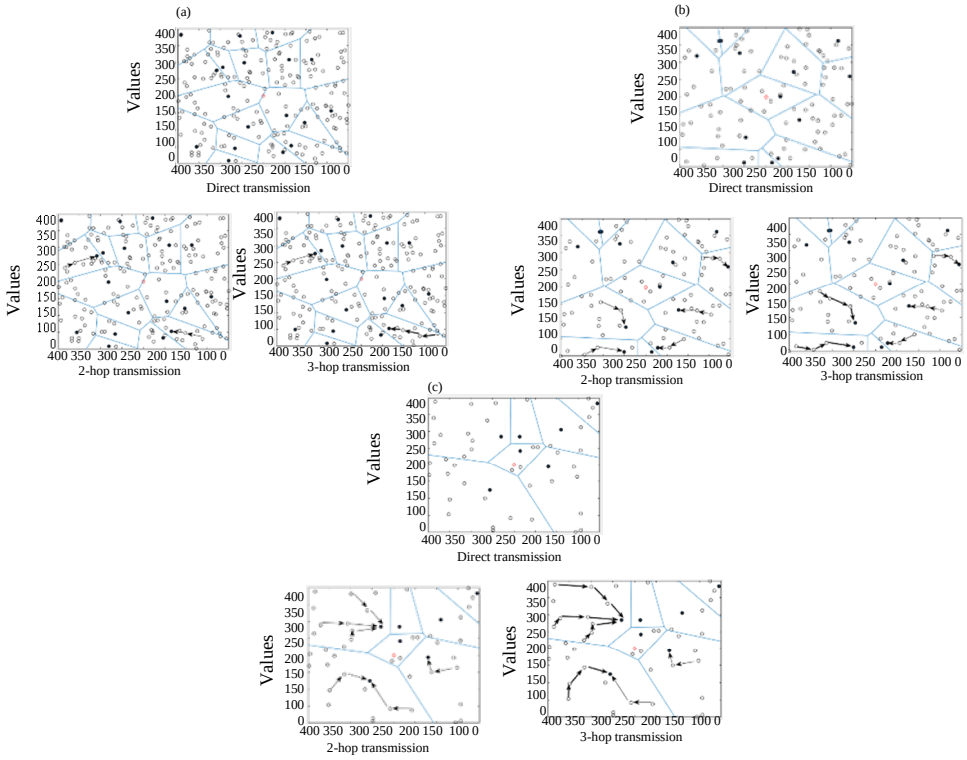

Fig. 4: Sensor field environment of the LEACH protocol using the proposed routing scheme for: a) Number of node:200; b) Number of node:100 and c) Number of node:50

First Node Dead (FND) is the round when the first node that consumes all the energy occurs. Therefore, FND can be a benchmark for comparing energy efficiency. In Table 4 when the number of nodes is 50, the FND of the LEACH protocol with 2-hop transmission increased about 8% from the existing protocol. And the FND of the LEACH protocol with 3-hop transmission increased about 11% from the existing protocol. Also, when the number of nodes is 10, the FND of the LEACH protocol with 2-hop transmission increased about 3% from the existing protocol. And the FND of the LEACH protocol with 3-hop transmission increased about 5% from the existing protocol. When the number of nodes is 200, the FND of the existing protocol and the FND of the LEACH protocol using the multi-hop transmission are almost unchanged.

CONCLUSION

In this study, we propose a inner multi hop transmission to improve the problem of transmission distances of member nodes due to the random selection of cluster heads. And we derive the minimum threshold distance for efficient multi-hop transmission in the cluster. That is, when the distance (d) between the member node and the cluster head is $d_{th\_2hop} \leq d < d_{th\_3hop}$, the 2-hop transmission is most efficient. And when the distance (d) between the member node and the cluster head is d_{th_3hop},, the 3-hop transmission is most efficient. In addition, inner cluster multi-hop is suitable in a sensor field environment where the node density is small or wide.

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