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Dual-hop Routing Protocol for Improvement of Energy Consumption in Layered WSN Sensor Field

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Abstract

This paper proposes to increase the node energy efficiency, which rapidly drops during the transmission of L-TEEN (Layered Threshold sensitive Energy Efficient sensor Network protocol), using the method of DL-TEEN (Dual-hop Layered TEEN). By introducing dual-hop method in the data transmission, the proposed single-hop method for short-range transmission and multi-hop transmission method between the cluster heads for remote transmission was introduce. By introducing a partial multi-hop method in the data transmission, a single-hop method for short range transmission method between the cluster heads for remote transmission was introduces. In the proposed DL-TEEN, the energy consumption of cluster head for remote transmission reduces and increases the energy efficiency of sensor node by reducing the transmission distance and simplifying the transmission routine for short-range transmission. As compared the general L-TEEN, it was adapted to a wider sensor field.

Keywords: *Routing Protocol, Layer, Multi-hop, Dual-hop, TEEN, L-TEEN, DL-TEEN*

1. Introduction

Recently, with the possibility of realizing the ubiquitous and technology on Internet of things becomes feasible, a study on the related technology of the Wireless Sensor Network which is the core technology that forms the ubiquitous network is attracting attention. In general, the Wireless Sensor Network consists of the sensor node that process and collects the data and the Base Station for aggregating the data. This sensor node periodically collects the environmental data such as temperature, humidity, illuminance and vibration, etc., and performs several processes and transmits them to the Base Station.

Due to the nature of being a wireless network, the sensor node operates with independent power which is difficult to recharge and transmits the data using a wireless communication method. Due to such characteristics, efficient use of limited power is the most important in the design of the Wireless Sensor

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Network [1]. Various methods are being studied in order to increase the overall lifespan by increasing the energy consumption efficiency of the Wireless Sensor Network. Among them, the efficient routing protocol is largely divided into horizontal, location-based and hierarchical, etc. Among them, various protocols based on LEACH (Low Energy Adaptive Clustering Hierarchy) of hierarchical routing are being proposed [2-6]. LEACH is an algorithm that divides the entire network into a random cluster and manages by forming the head for each cluster [7]. The TEEN (Threshold sensitive Energy Efficient sensor Network protocol) is representative routing protocol of reactive type sensor network. This protocol elects the cluster head using stochastic threshold and forms a cluster. After clustering, every cluster head gathers data from its member node and transmits to the Base Station. The TEEN decides save and transmit the sensed data using two thresholds called Hard threshold(Ht) and Soft threshold(St). These thresholds al-ready broadcasted in the cluster formation process.

In the paper, it proposes an improved algorithm of DL-TEEN (Dual-hop Layered TEEN) by focusing on the phenomenon of a rapid drop in energy efficiency [8] which can occur when the cluster head becomes farther from the Base Station or when the sensor field becomes wider.

DL-TEEN introduces a new hierarchical layer and uses the dual-hop transmission method different from the previous L-TEEN. This dual-hop transmission method will allow the general nodes closer to the Base Station to use a single-hop transmission and the cluster heads far from the Base Station to use a multi-hop transmission method [9].

2. Related Works

2.1. LEACH Protocol

LEACH is the most well-known cluster-based hierarchical routing protocol proposed by W. Heinzelman in 2000 [7, 9]. LEACH divides the entire network into several clusters and has a hierarchical structure of classifying the nodes that form the clusters into the cluster head as the upper node and member node as the lower node. The member node periodically senses the surrounding environment and transmits the collected data to the cluster head. The cluster head after receiving this data merges and compresses the data to reduce the amount and transmits the data to the Base Station [7]. Due to such hierarchical structure, the member node of LEACH can reduce the energy consumption due to a shorter transmission distance than the direct transmission. However, the cluster head has high energy consumption due to its role of collecting, processing and transmitting the data to the Base Station. To prevent the excessive energy consumption of such cluster head, the LEACH protocol periodically changes the cluster head thereby dispersing the energy.

The process of LEACH protocol consists of Setup Phase and Steady Phase. First, in the setup phase, an election of probabilistic cluster head using Stochastic Threshold equation (1) is made [7].

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

P – Election probability of cluster head
T(n) – Threshold value to compare
r – Current round
G – Set of nodes which did not become cluster heads in the previous round

Here, the elected cluster head sends out the ADV (advertisement) message including its own information. General nodes within this range sends out the Join-REQ message which informs the CH that it belongs to the corresponding cluster as a cluster head and thereby forms the containment relationship and assigns the time slot to each node through TDMA scheduling. Afterwards in normal state, the corresponding node of each time slot awakens to transmit their data and goes back to the sleep state. The cluster head collects and processes the data of the members and transmits the data to the Base Station using a code division transmission method. Periodically repeating these two processes are called a single round. The round configuration of LEACH is shown in Figure 1 [10].

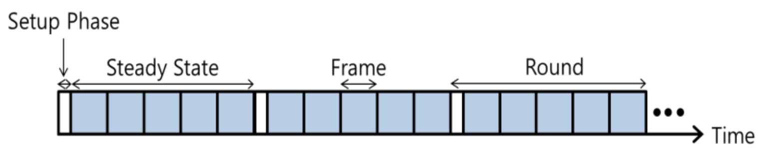

Figure 1. Round configuration of LEACH

2.2. TEEN

TEEN(Threshold sensitive Energy Efficient sensor Network protocol) is the stochastic-hierarchical protocol in the same way as LEACH. This protocol uses the same clustering algorithm of LEACH, however the sensor node doesn't transmit the sensed data periodically. To filter for data collection or transmission, the TEEN uses two threshold called the H_t(Hard threshold) and S_t(Soft threshold). These two thresholds broadcasted in clustering process. After this broadcast, the first data collection is beginning. If the sensed data of sensor nodes is bigger than H_t, all the node saves it and it transmits the saved data at own time slot.

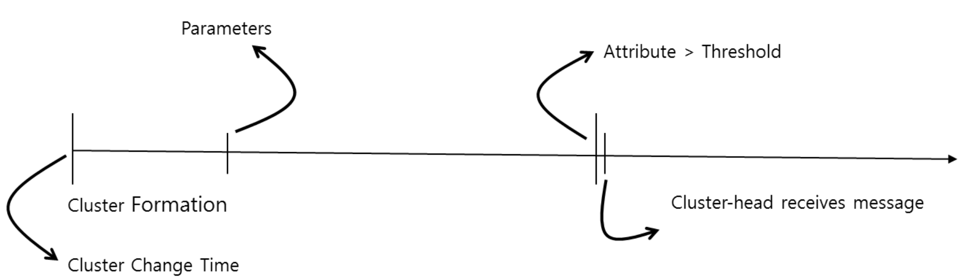

Figure 2. Timeline of TEEN

In clustering process, TEEN sets two thresholds for adjust the data collection flexibly. For this reason TEEN is suitable to observe drastic change like seismic monitoring system and fire detection system.

2.3. MTE Protocol

MTE is a routing protocol that uses a multi-hop transmission method. This protocol tracks the shortest distance through other nodes in the moving direction when all nodes are transmitting the data to the Base Station. This method does not have a big energy consumption when the node transmits the data to the Base Station but increases the amount of data as the transmissions are repeated over to the next node thus the energy consumption proportional to hop will occur. The amount of data to transfer will become greater as it becomes closer to the Base Station with a rapid increase in energy consumption [11].

3. L-TEEN: Layered TEEN

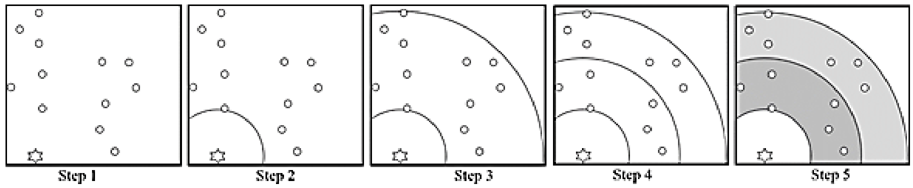

Figure 3. Step of Division Layer

- *Step 1*: It is assumed that the sensor node is shown on the left in the sensor field. The circle is a sensor node, and the Base Station is shown as a Star.
- *Step 2*: Measure the distance to the closest node from Base Station.
- *Step 3*: Measure the distance to the farthest node from Base Station.
- *Step 4*: Using the mid-point of distance between the closest node from Base Station and the farthest node from Base Station, Divided the sensor field layer.
- *Step 5*: The layer of light gray which is far from the Base Station, we called the Outer Layer. The layer of dark gray which is near from the Base Station, we called the Inner Layer.

After the divided Layer, it performs the clustering as using protocols like TEEN in each layer. After it completed the clustering each layer, member nodes in the cluster are sent their sensing data to the cluster head. Cluster Head Nodes are aggregation the received data from the member node. Cluster Head Nodes in the Outer Layer are transmitted aggregation data to the closest Cluster Head Node in the Inner Layer. Then, Cluster Head Nodes in the Inner Layer aggregates the data of the Outer Layer. Finally, Cluster Head Nodes in the Inner Layer are transmitted data to the Base Station.

However, if you divided the layers, this is not always ideal for clustering.

3.1. Proposed Algorithm

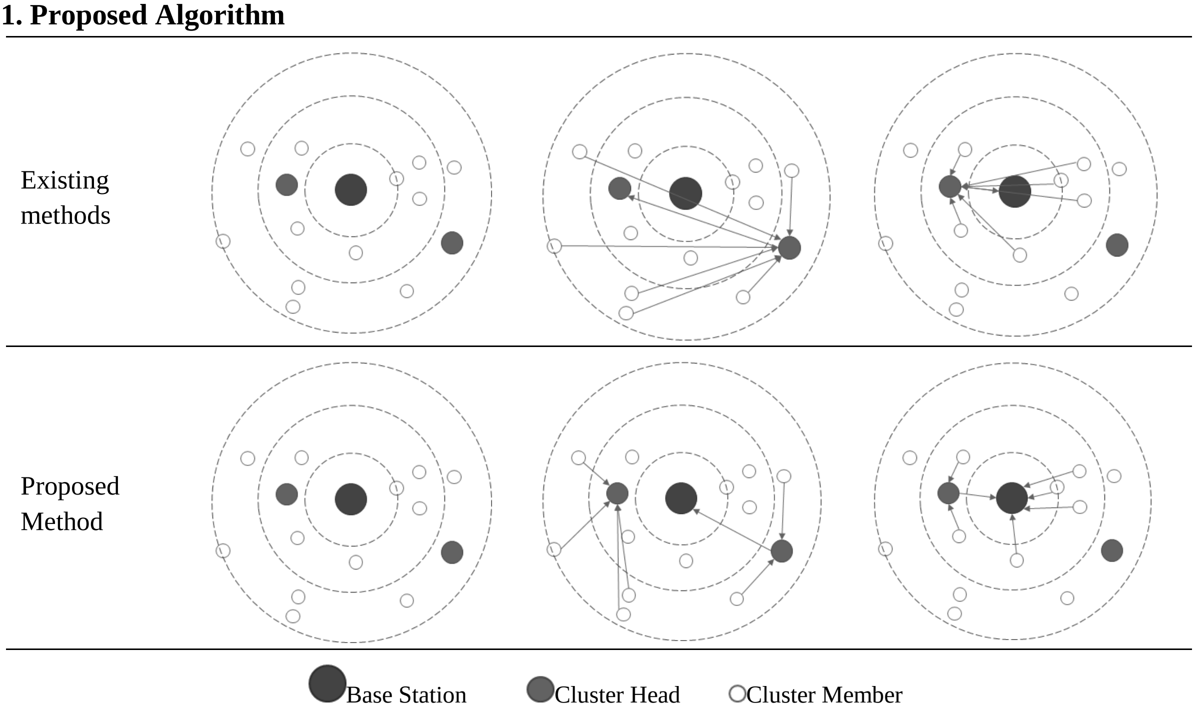

Figure 4. Comparison of method

To solve this problem, we proposed the improving method based on Dual-hop transmission.

Usually Cluster member nodes are transmits the data using Multi-hop. But applying the dual-hop transmission, the Cluster member nodes are the transmission method determined according to the conditions.

Cluster member nodes are sends data to one of the following nodes: Cluster Head in current layer and Cluster Head in lower layer and Base Station.

Figure 4 is a comparison of the proposed method and the existing method. It can see that data is transmitted more efficient.

4. Simulation

4.1. Test Environment

In order to verify the proposed algorithm, L-TEEN and DL-TEEN protocol sensor field was structured using the MATLAB for simulation. In order to demonstrate the effectiveness of the algorithm, the sensor field has considered the two fields of different sizes in order to compare the energy efficiency according to the changes of field width. As an index for comparing the energy efficiency, the number of survival node of two algorithms, FND (First Node Dead), and 80% Node Alive was measured.

When configuring the simulation, the First Order Radio Model [7, 14] like the Figure 5 was used for the data transmission and the parameter of each state is shown in the Table 2 and 3.

Table 2. Simulation parameters

Simulation Environment	
Sensor Field	200 * 200, 400 * 400
Sensor Node	100, random position

Table 3. Parameter of First Order Radio Model

Radio Model Parameter	
Initial Energy	0.5 J
Message Size	2000 bit
Transmit / Receive Energy	50 nJ/bit
Amplifier Energy	10 pJ/bit/m^2

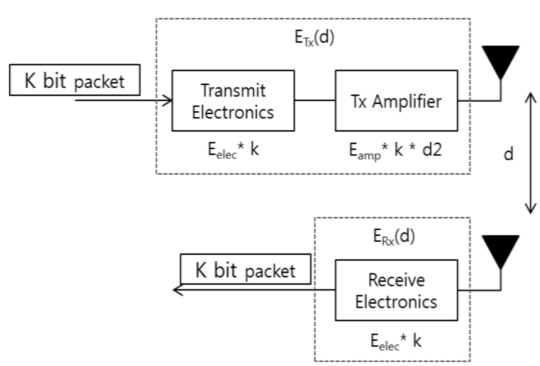

Figure 5. First Order Radio Model

4.2. Simulation Results and Analysis

In order to compare the energy efficiency of L-TEEN and proposed protocol, the survival node per round in two fields having the width of 200 * 200 and 400 * 400 was measured and compared.

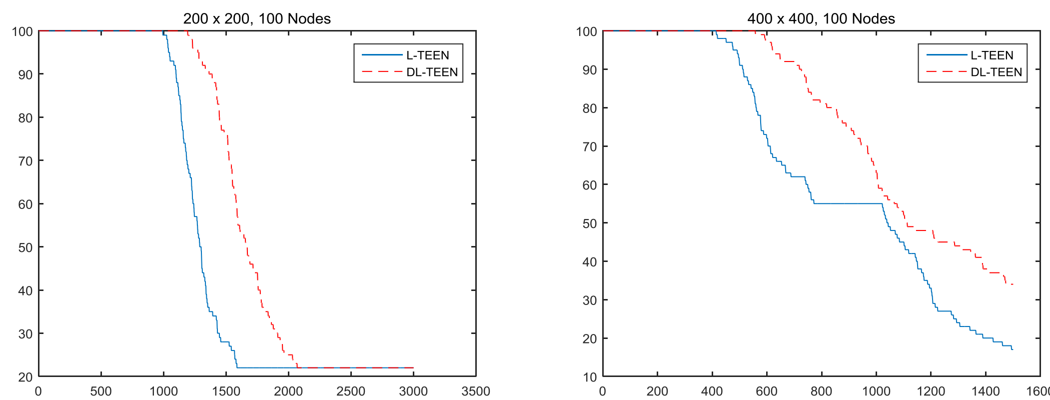

Figure 6. Number of survival node of two protocols (Left: 200*200, Right: 400*400)

The graph of Figure 6 is the number of survival node in 200*200 field and 400*400 field.

Table 4. FND and LND of two protocols

Field		L-TEEN	DL-TEEN
200 * 200	FND	993	1192
	80% Node Alive	1141	1446
400 * 400	FND	414	557
	80% Node Alive	560	819

The table 4 represents the FND and 80% Node Alive of two algorithms. Although there are no significant performance changes in the 200*200 field, in the field wider than 400*400, FND had increased 135% compared to L-TEEN and 80% Node Alive had increased 146% compared to L-TEEN.

5. Conclusion

In the proposed DL-TEEN, the transmission method of L-TEEN was changed to dual-hop (single-hop + multi-hop) method to improve on the transmission distance and at the same time, the phenomenon of energy consumption bias near the Base Station of multi-hop method was improved through a dynamic clustering and partial single-hop transmission. As a result, the data transmission phase of the nodes close to the Base Station became shorter along with the total transmission distance and the amount of energy used for this process has decreased. Conclusively, DL-TEEN proposed in this paper has used the dual-hop transmission method to alleviate the problems of L-TEEN; a rapid decrease in the lifespan of the node as the sensor field became wider.

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