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Routing Tree with Cluster Head Selection in a Wireless Sensor Network

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Abstract

Wireless sensor network is attractive to researcher and commercial users. It provides several usages in different areas, but it also has a weakness. Energy restriction of sensor network leads to several research outputs. In this paper, we consider cluster header selection mechanism with routing tree to the sink node. We select cluster head as small as possible and it also provides connectivity to the sink node with routing tree.

Keywords*: cluster based routing, energy efficient, wireless sensor network*

1. Introduction

Wireless sensor network is an attractive research topic on several applications. The development of MEMS (micro-electro-mechanical system) technology leads to low-cost, high quality sensor [1,26]. Tiny sensor has sensing unit, wireless communication and processing unit. Wireless sensor network is applied to various applications like as battlefield, agriculture area, fire detection and so on. Recently due to the development of sensor hardware, it is possible that sensor network has mobile characteristics, rechargeable robot, mobility sink, and so on. But most of sensor networks are still facing difficulties with energy saving problem. The researches for efficient energy in a wireless sensor network are being made from several aspects - topology configuration, data flooding, routing, aggregation, data fusion, target tracking [3-7, 20, 23].

We also consider energy saving aspects of wireless sensor network with cluster based configuration and routing. Researches about Cluster configuration provide many ideas for energy efficiency [8-14, 19-24]. Cluster based method can be the topic of topology and that of routing. We consider two aspects of topology configuration and routing of data reporting to the sink node. Our proposed method [18] can provide not only efficient cluster head selection method but also routing tree from sink node to cluster head. When the cluster head is selected, it uses its hop count which is derived from transmission range. This method reduce the count of cluster heads in a same hop count but decrease the probability of upstream cluster head in transmission range. In this paper, we make an improvement with change of cluster head transmission radius. To avoid additional relaying node, we use smaller transmission range when the network calculates hop count of sensor node.

The rest of this paper is organized as follows. In Section 2, we introduce a cluster based routing protocol with related work. In Section 3 we propose cluster head selection mechanism with reduced transmission range for high connectivity to the sink node. And we evaluate the proposed method through simulation in Section 4, and finally conclude this paper in Section 5.

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2. Related Work

Cluster based routing protocols are researched for a long time from beginning of wireless sensor network. Figure 1 shows the classification of cluster based routing protocols [2].

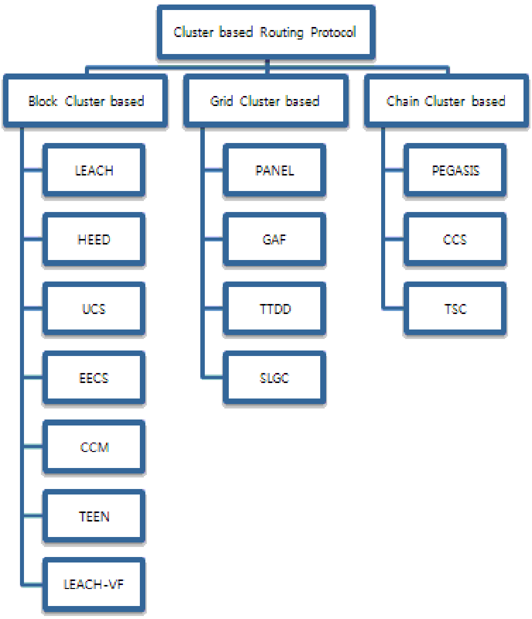


Figure 1. Classification of Cluster Based Routing Protocol

LEACH [15] is a representative mechanism of clustering in a wireless sensor network. It provides a cluster based data routing and transmits data to the sink node by cluster head. Because cluster head transmits the data to the sink node directly regardless of its position, LEACH creates excessive use of energy from cluster head.

The radio model which used in PEGASIS, LEACH [15, 16], the energy to transmit data is proportionally increased by data bits and the square of distance. In this model, a radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and ε_{amp} = 100 pJ/bit/m^2 for the transmitter amplifier [15, 16].

Transmitting

$E_{Tx}(k, d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$

$E_{Tx}(k, d) = E_{elec} * k + \varepsilon_{amp} * k * d^2$

Receiving

$E_{Rx}(k) = E_{Rx-elec}(k)$

$E_{Rx}(k) = E_{elec} * k$

To compare with our proposed method, we exclude methods in which cluster head transmits data to the sink node directly. Because direct transmission to the sink node uses much energy as shown in previous formula, our proposed method considers hop by hop transmission to the sink node.

We introduce PEGASIS [16] and GAF[17] which both of them can use relaying node to the sink node for data reporting.

PEGASIS is a chain based routing protocol. Each sensor node in PEGASIS configures network chain with its neighbor sensor nodes. It uses global knowledge of the network with greedy algorithm like as traveling salesman problem.

GAF is a grid based routing protocol. In this protocol, each node can calculate its "virtual grid" using location information based on GPS. The virtual grid size r is given by the formula [18]:

$$r \leq R / \sqrt{5} \quad (R \text{ is the radio range})$$

These two methods are based that each sensor has location information. We just use hop count from sink node for location information. Figure 2 shows the routing operation of LEACH, PEGASIS and GAF.

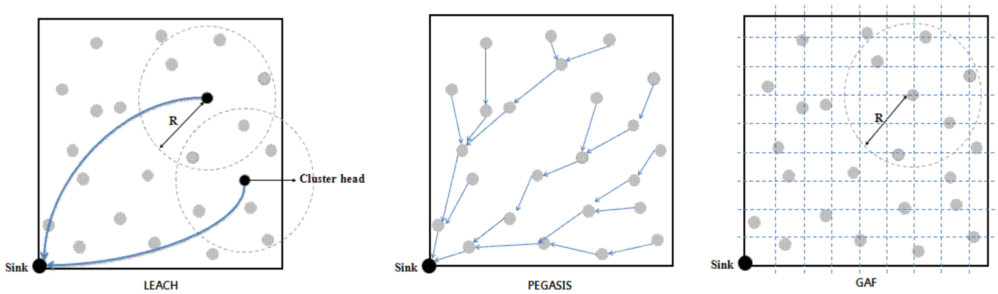


Figure 2. Routing Operation of LEACH, PEGASIS and GAF

3. Cluster Head Selection with Routing Tree

For energy efficiency in a wireless sensor network, we proposed cluster based routing method [18]. Routing tree from sink node to cluster heads is automatically generated when the network decides cluster head selection. Data is reporting from cluster head to the sink node by cluster head's routing tree. Cluster head is role of data collection, data fusion and data relating to the sink node. In this method, cluster head is selected within same hop count. It also uses transmission range of cluster head, so it select cluster head as small as within same hop count. As it uses same hop count, it has difficulty in providing connectivity to the sink node for all cluster head. This method additionally processes secondary relaying node selection mechanism.

For decreasing this additional operation for relaying node selection, we propose that smaller transmission range is used only when hop count is calculated. This method increases the probability of connectivity to the upstream cluster head so that it provides the routing path to the sink node hop by hop. The sensor node existing overlapping area of cluster head can select its cluster head depending on cluster head hop count, stronger signal, residual energy and so on.

Figure 3 shows that the reduced transmission range is applied in a sensing field. Our improved proposal can make a high probability of existing upstream cluster head in a transmission range of cluster head. We show the result by simulation at the next section.

As the more reduced transmission range is used for hop calculation, the existence probability of upstream cluster head is raised but the total counts of cluster head in a sensing field are increased too. In order to reduce the count of cluster head, cluster head is selected to minimize the overlap area in a same hop count. Cluster head does not have any other cluster head with same hop count in a transmission range.

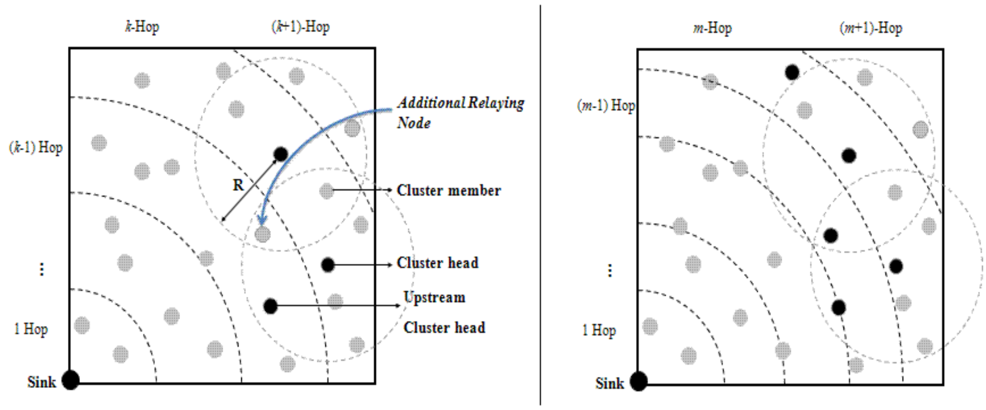


Figure 3. Transmission Range is Reduced when Hop Count is Calculated

4. Performance Evaluation

In this section, we show the result of our simulation with proposed method and compare with GAF protocol.

4.1. Simulation Parameters

We simulate our proposed scheme with simple test environments. We just consider the position of sensor nodes, and calculate the counts of cluster head with distributed manner. The ratio of connectivity to the sink node from cluster head is also measured with additional relaying node. Because we try to show the validity of our proposed mechanism, we simplify the elements of energy.

Sensor node is sprayed with uniformly random probability in sensing area. Simulated sensing area is a square and sink node is placed in the corner of sensing area. We scattered sensor densely in a field. The parameter sets used for simulation are listed in Table 1.

Table 1. Simulation Parameters

Parameter	Size
Network	500 x 500
Number of sensor nodes	1000
Transmission range	50 ~ 100

4.2. Simulation Results

Figure 4 shows 500 x 500 sensing field and selected cluster heads when original transmission range is used for hop count calculation. The number of cluster heads is 29 and the number of relaying nodes is 12.

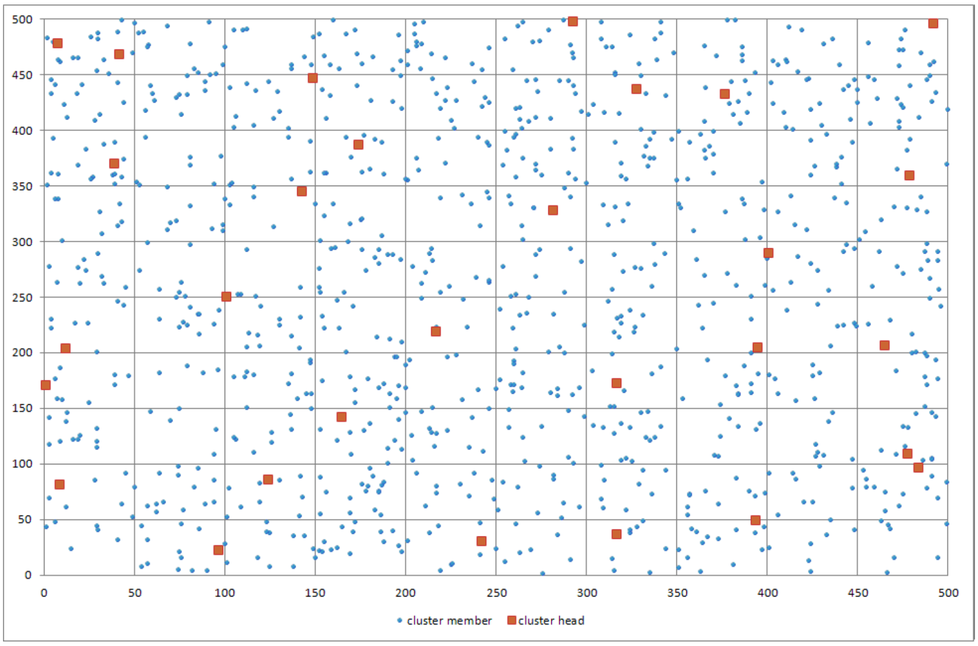


Figure 4. Cluster Head Selection without Reduced Transmission Range (Transmission Range 100, Network Size 500 X 500, Sensor Nodes 1000)

Figure 5 shows that the number of cluster heads and additional relaying nodes according to the reduced proportion of transmission range. As the smaller ratio of transmission range is applied, the more cluster heads are selected and the smaller additional relaying nodes are selected. With smaller additional operation of relaying node selection, proposed method shows that selected cluster head has a hop by hop routing path to the sink node with a high probability.

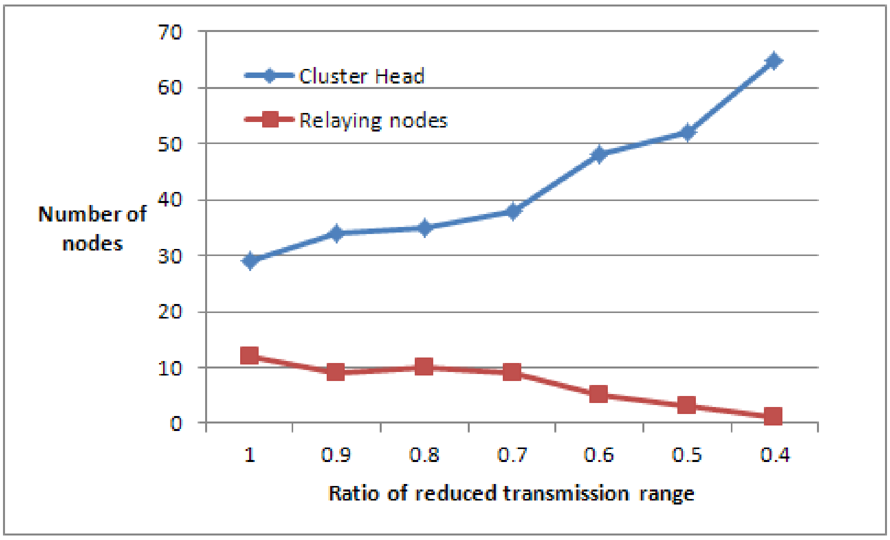
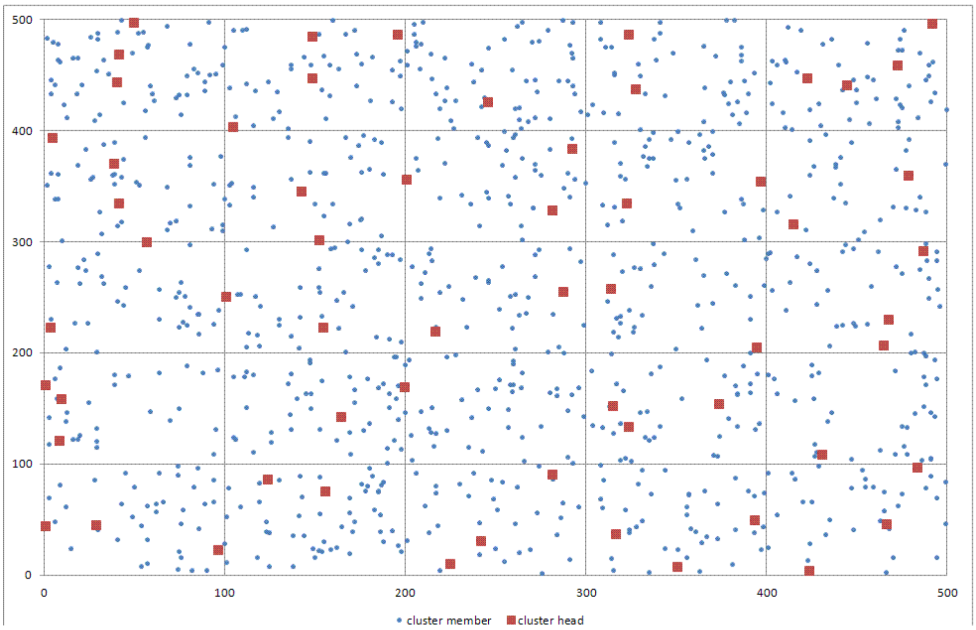
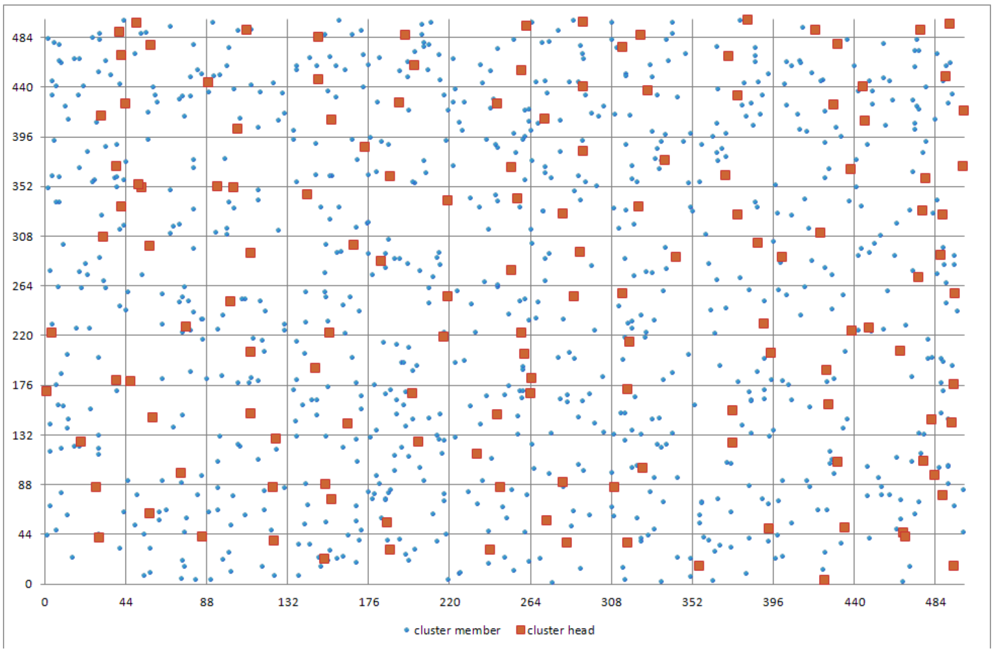


Figure 5. Counts of Cluster Head and Relaying Nodes (Transmission Range 100, network size 500 x 500, sensor nodes 1000)



(a) Proposed Method



(b) GAF Protocol

Figure 6. Cluster Head Counts with Proposed Method and GAF (*r* is used *R*/√5)

Figure 6 (a) shows that our proposed method selects 64 of cluster heads and 2 of relaying nodes where the network uses the reduced transmission range with *R*/√5 for comparing with GAF. Figure 6 (b) shows that GAF protocol produces 144 of cluster heads with virtual grid size with *R*/√5. Our hop based protocol with reduced transmission range produces small number of cluster heads compared with GAF.

5. Conclusion and Future Work

In this paper, we propose cluster based routing tree with reduced transmission range for hop count. To increasing hop by hop routing connectivity to the sink node from cluster head to the sink node, we calculate hop count with smaller transmission range. As a result, the count of cluster head nodes is increased a little but the count of additional relaying nodes is decreased.

On the next research, we will analyze the optimized ratio of transmission range depends on the density of sensor nodes. Because our proposed method operates well in dense network, we also need to consider a sparse network.

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