# 센서 네트워크를 위한 레벨 모델 기반 체인 클러스터 라우팅 프로토콜

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요약

무선 센서 네트워크에서의 라우팅 알고리즘의 가장 중요한 요소는 센서 노드의 에너지 효율성 구현에 있다. 효율적인 라우팅 프로토콜 설계를 통해 센서 노드의 에너지 효율 향상을 통한 센서 네트워크의 라이프 타임을 증대시키고, 노드 간 데이터 전송에 있어서의 신뢰성 확보가 필요하다. 본 논문에서는 센서 노드의 클러스터를 구성하고, 각 클러스터 헤드 노드 간의 구조적 계층 모델을 통해 에너지 효율적인 레벨 모델 기반 체인 클러스터 라우팅 프로토콜(ECLR: Energy-Efficient Chain-Cluster Routing Protocol)을 제안하였다. 또한, MATLAB을 이용한 시뮬레이션을 통해 기존의 클러스터 기반 라우팅 프로토콜인 PEGASIS와 LEACH 보다 ECLR이 에너지 효율성이 증대되었음을 확인하였다.

# Energy-Efficient Chain-Cluster Routing Protocol Based on Level Model for Wireless Sensor Network

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ABSTRACT

The most important thing in wireless sensor network routing algorithm is how to save sensor nodes energy. The main goal of routing protocols is to find ways for improvement of energy efficiency and reliable transmission of sensed data to sink. We proposed a new routing protocol for wireless sensor networks called Energy-Efficient Chain-Cluster Routing Protocol Base on Level Model (ECLR). ECLR makes clusters and elects cluster head nodes. Cluster head nodes make routing chain hierarchically. By MATLAB simulation, we compared ECLR and other cluster based routing protocols, PEGASIS and LEACH. Simulation results show the improvement of energy efficiency of ECLR.

Key Words : Sensor Network, Routing Protocol, LEACH, PEGASIS, Energy Consumption, System Lifetime

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## Ⅰ. Introduction

A wireless sensor network is an active research area with numerous workshops and conferences arranged each year. Wireless sensor network consist of a large number of sensors and many base station (BS) that have capabilities of sensing. The sensors are small, have a limited resources: battery power, computation, communication range and memory [1].

Many routing protocols have been proposed for wireless sensor networks. The main goal the routing protocols in wireless sensor networks is to find the ways for improvement of sensed data to the sink [2]. Routing protocol in wireless sensor networks can be classified into several network structures as flat network routing, hierarchical network routing, and Location-based network routing [3]. Hierarchical network routing can be classified again according to the clustering tactics as distributed or centralized fashion [2]. Example of hierarchical network routing including LEACH (Low-Energy Adaptive Clustering Hierarchy) [4], PEGASIS (Power Efficient Gathering in Sensor Information System) [5][6], In a hierarchical network routing architecture, higher energy nodes can be used to process and send information while low energy nodes can be used to perform the sensing in the proximity of the target, this means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficient. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the base station [3].

The reminder of the paper is organized as follows: Section 2 related work of wireless sensor network. In Section 3 routing algorithm proposed, provides the simulation results. Finally, Section 5 offers conclusions.

## Ⅱ. Related Work

Hierarchical routing performs energy-efficient routing in WSNs, and contributes to overall system scalability and lifetime. In a hierarchical architecture, sensors organize themselves into clusters and each cluster has a cluster head [8].

### 2.1 LEACH

Heinzelman. et. al. [9] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes. As cluster-heads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network [6]. LEACH uses localized coordination to enable scalability and robustness for dynamic networks, and incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station.

In LEACH the operation is divided into rounds, during each round a different set of nodes are cluster-heads (CH). Nodes that have been cluster heads cannot become cluster heads again for P rounds. Thereafter, each node has a $1/p$ probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster to transmit data. The cluster heads aggregate and compress the data and forward it to the base station, thus it extends the lifetime of major nodes. In this algorithm, the energy consumption will distribute almost uniformly among all nodes and the non-head nodes are turning off as much as possible. LEACH assumes that all nodes are in wireless transmission range of the base station which is not the case in many sensor deployments. In each round, LEACH has cluster heads comprising 5% of total nodes. It uses Time Division Multiple Access (TDMA) as a scheduling mechanism which makes it prone to long delays when applied to large sensor networks [8].

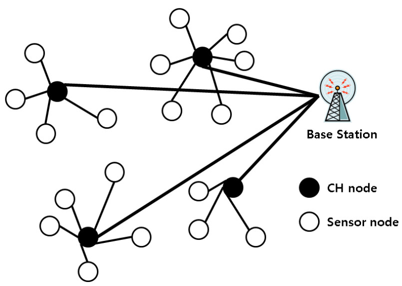


그림 1. LEACH 알고리즘
Fig. 1. LEACH

## 2.2 PEGASIS

PEGASIS (Power-Efficient Gathering in Sensor Information System) is improved protocol where only one node is chosen a head node which sends the fuses data to the BS per round [6]. The key idea in PEGASIS is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor. Gathered data moves from node to node, get fused, and eventually a designated node transmits to the BS [5].

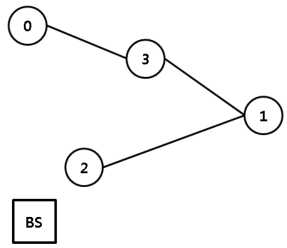


그림 2. greedy 알고리즘에 따른 체인 형성
Fig. 2. Chain construction using the greedy algorithm

In PEGASIS to construct the chain, we start with the furthest node from the BS. We begin with this node in order to make sure that nodes farther from the BS have close neighbors, as in the greedy algorithm the neighbor distances will increase gradually since nodes already on the chain cannot be revisited. Figure 2 shows node 0 connecting to node 3, node 3 connecting to node 1, and node 1 connecting to node 2 in that order. When a node dies, the chain is reconstructed in the same manner to bypass the dead node [5].

Advantages of PEGASIS over LEACH, compare to leach transmitting distance for most of the node reduces in PEGASIS, messages received by each head node are at most 2 in PEGASIS is less compared to leach, since each node gets selected once, energy dissipation is balanced among sensor nodes [6]. PEGASIS also have weaknesses including when a head node is selected, there is no consideration how far the BS is located from head node, when head node is selected its energy level is not considered, since there is only one node head, it may be the bottle neck of the network causing delay, redundant transmission of data as only one head node is selected.[6].

## III. ECLR Protocol

ECLR is a clustering routing in wireless sensor networks that designed by creating clusters in an X and Y coordinates. This protocol can be applied to network which has monitoring messages that continues flow into the sink and correlated data between neighboring nodes. ECLR combines clustering base on level and distributed algorithm, considers the coordinate X and Y, it will provide the operation with high energy dissipation in distributed algorithm to the base station to utilize all the powerful processing capabilities of base station, while a simple distributed algorithm solved by the cooperation of sensor nodes. ECLR operation is divided into three phases, cluster-formation phase, cluster-head-selection phase and steady-state phase.

In the cluster-formation phase, we use distributed algorithm to initiate the network. After initialization, in the first level clustering, according to the distance in Y-direction between sensing region and base station, the sensing region can be divided into several clusters with the same width (cluster level 1), after that for the second level clustering this will be subdivided into several kinds of number of clusters, then the network works periodically, and organizes into rounds. The last two phases mentioned above rotate periodically in each round.

a. Cluster-Formation Phase

The operation of network begins with cluster-formation phase. In this phase, the networks formed several clusters for the first level and then followed by the formation of clusters on the second level. Sensor nodes in each cluster construct chain using greedy algorithm.

b. Cluster-Head-Selection Phase

The process of this phase is that the base station chooses a cluster-head in each cluster by considering the highest energy and the closest distance to the base station. Then base station chooses cluster head leader for each level also by considering the highest energy and the closest distance to the base station. Furthermore, top cluster head leader will be selected among the cluster head leader of each level cluster by considering the highest energy and the closest distance to the base station.

c. Steady-State Phase

After the proposed algorithm performs the chain construction in each level and head node in each cluster selected, each node delivers its own data to its neighbor sensor node along the chain. And also after cluster head leader for each level is selected, each cluster head will choose where to send data, in this proposed algorithm we make some possibility for cluster head leader to send data to the top cluster head leader:

- The cluster head will check the top cluster head leader in the left, top, right and bottom side. From the four cluster head:
- If there is a top cluster head leader in the left or right(same level), then he will transmit to it.
- If the left or right side only the cluster head leader, then he will transmit it to the cluster head leader.
- If the left or right side only cluster head, then will check upwards and downwards to find a top cluster head leader (priority) or other cluster head leader as a destination to transmit messages.
- If not managed to find, so it will transmit to the cluster head to the left or right depending on the

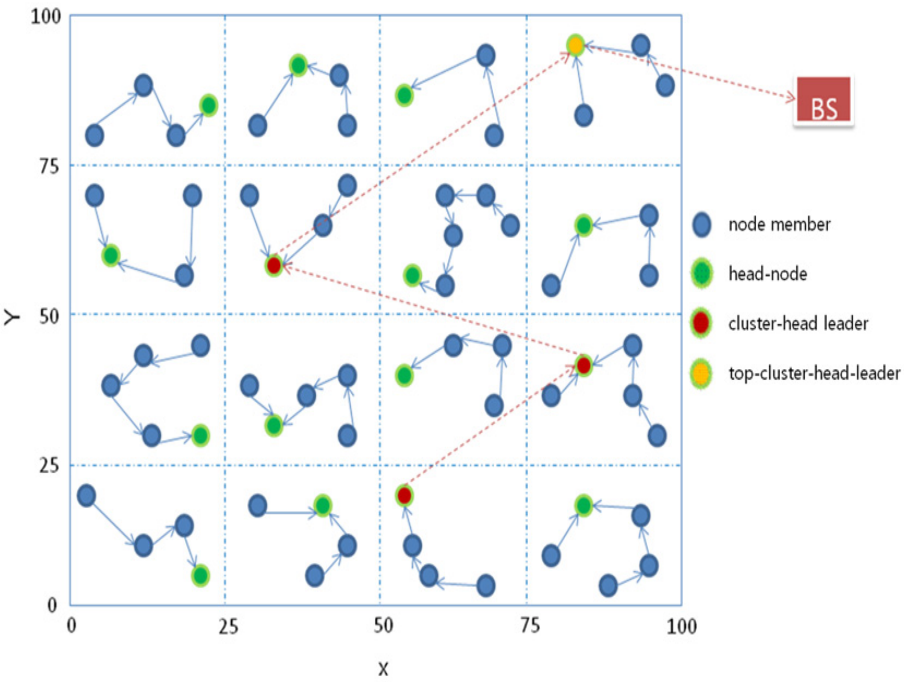


그림 3. 클러스터 구성도
Fig. 3. A snapshot of cluster formation

direction in which the cluster head leader in level are.

In the process of joining the cluster heads, we prioritize the transmission of data in the same level throughout the levels above and below, it there is no cluster head leader.

This algorithm is the same process similar with PEGASIS in fuses data and transmits the data.

## Ⅳ. Simulation Results

In our simulation, we assume that 100 sensor nodes are scattered randomly in the region with $100m \times 100m$ area, the coordinate of base station is (125,75) and also we consider four different kind number of clusters: 4 clusters, 9 clusters, 16 clusters and 25 clusters. We also consider three different initial energy: 0.25*J*, 0.5*J*, 1*J*.

Assuming the energy parameters are set as $Eelec$=50$nJ/bit$, $Eamp$=100$pJ/bit/m2$ and $ETx \propto d^2$(the distance between transmitter and receiver) and a message is $k$=2000 *bits* data.

This simulation is run up to ten times and after that we took an average of 10 times the simulation for comparison. In the first simulation, we evaluate the total remaining energy all sensor nodes, system lifetime, percentage of node death and also we evaluate performance comparison among several cluster number by using ECLR algorithm. Our simulations show the following results.

a. The remaining energy vs number of rounds

- Initial energy 0.25 J/node, 2500 rounds, 4 clusters

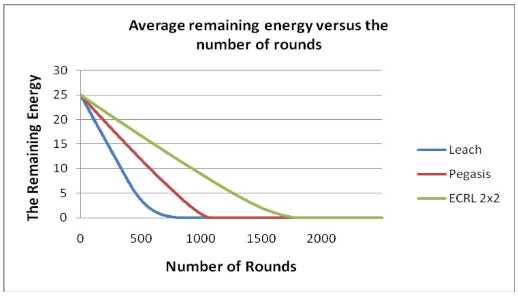


그림 4. 라운드별 에너지 잔량(초기 에너지 0.25J)
Fig. 4. Average remaining energy versus number of rounds with initial energy 0.25 J/node

Figure 4 show LEACH runs out the remaining energy about 895 rounds, the remaining energy of ECLR about 10.5 J and PEGASIS about 2.6 J. While PEGASIS runs out of energy about 7J.

- Initial energy 0.5 J/node, 2500 rounds, 4 clusters

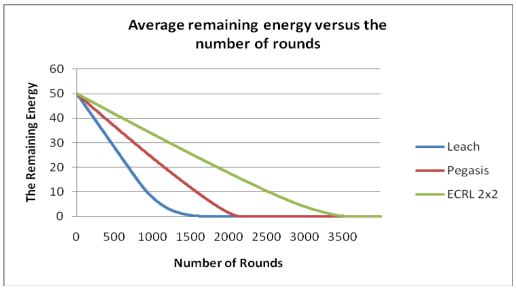


그림 5. 라운드별 에너지 잔량(초기 에너지 0.5J)
Fig. 5. Average remaining energy versus number of rounds with initial energy 0.5 J/node

Figure 5 show LEACH runs out the remaining energy about 1868 rounds, the remaining energy of ECLR is still 19.8 J and PEGASIS about 3.8 J. While PEGASIS runs out of energy about 2191 rounds ECLR have remaining energy about 14.9 J.

- Initial energy 1 J/node, 2500 rounds, 4 clusters

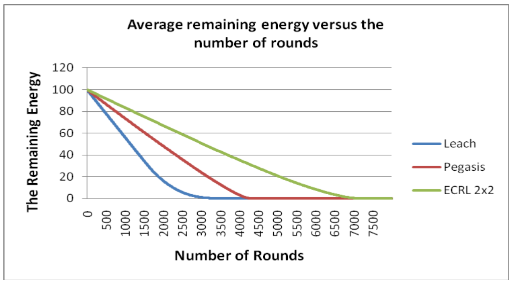


그림 6. 라운드별 에너지 잔량(초기 에너지 1J)
Fig. 6. Average remaining energy versus number of rounds with initial energy 1 J/node

Figure 6 show LEACH runs out the remaining energy about 3754 rounds, the remaining energy of ECLR is still 39 J and PEGASIS about 7.7 J. While PEGASIS runs out of energy about 2191 rounds ECLR have remaining energy about 29.3 J.

b. Comparision of system lifetime (Number of nodes alive versus number of rounds)

- Initial energy 0.25 J/node, 2500 rounds, 4 clusters

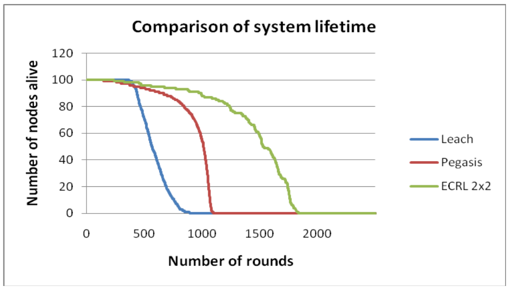


그림 7. 라운드에 따른 노드 생존율(초기 에너지 0.25J)
Fig. 7. Performance comparison of system lifetime with number of rounds with initial energy 0.25 J/node

Figure 7 shows that the network lifetime of ECLR is out performs than the LEACH and PEGASIS.

When nodes in LEACH out at 894 rounds ECLR still has 91 nodes and PEGASIS 75 nodes. ECLR nodes will be exhausted in 1833 rounds and PEGASIS in 1101 rounds.

- Initial energy 0.5 J/node, 4000 rounds, 4 clusters

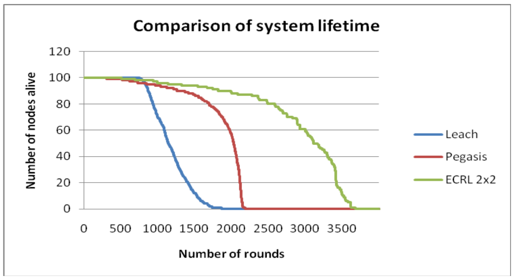


그림 8. 라운드에 따른 노드 생존율(초기 에너지 0.5J)

Fig. 8. Performance comparison of system lifetime with number of rounds with initial energy 0.5 J/node

Figure 8 shows that the network lifetime of ECLR is out performs than the LEACH and PEGASIS. When nodes in LEACH out at 1868 rounds ECLR still has 90 nodes and PEGASIS 71 nodes. ECLR nodes will be exhausted in 3683 rounds and PEGASIS in 2191 rounds.

- Initial energy 1 J/node, 8000 rounds, 4 clusters

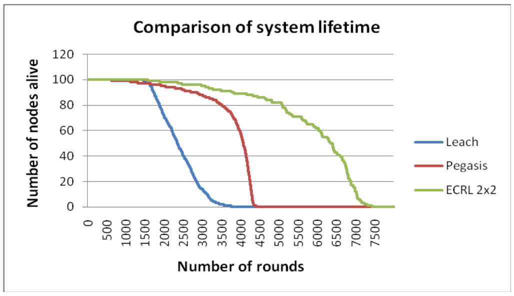


그림 9. 라운드에 따른 노드 생존율(초기 에너지 1J)

Fig. 9. Performance comparison of system lifetime with number of rounds with initial energy 1 J/node

Figure 9 shows that the network lifetime of ECLR is out performs than the LEACH and PEGASIS. When nodes in LEACH out at 3754 rounds ECLR still has 91 nodes and PEGASIS 74 nodes. ECLR nodes will be exhausted in 7439 rounds and PEGASIS in 4413 rounds.

The better performance is due to some reasons. Firstly, the ECLR protocol directly selects the node with the maximum rest energy as the cluster-head, cluster-head-leader and top-cluster-head leader which spends the most energy, so that the network energy distribution is balanced and the lifetime of node death is prolonged. Secondly, data aggregation technique used in the process of transmitting data which increases the network lifetime efficiently.

## Ⅴ. Conclusions

Some conclusions can be drawn from these simulation experiments. By clustering can increase energy dissipation in the process of routing and also reduce the time needed to reach the BS. Distributing the energy load among nodes increase the lifetime and quality of the network.

The protocol utilizes a special method on cluster division which saves much energy consumption on overheads produced by network rebuilding, and take the maximum-rest-energy as the criterion to select cluster-head-leader node, in order to balance the network energy distribution. The ECLR protocol outperforms LEACH and PEGASIS. In terms of network lifetime, ECLR performs 3 times more than LEACH and 1.5 times more than PEGASIS.

## Ⅵ. Future Works

Future work could be taken in a number of directions. Obvious improvements to the ECLR protocol using two network structure. A combination between hierarchical routing and location based routing to improve network area in order to reach a large area.

A method for rotating cluster head leader during the steady-state phase without interrupting data reporting would be a useful feature for scenarios that have widely varying transmission costs between clusters. Support for dynamically determining the reclustering period would not only reduce configuration, but better distribute energy load as sensors die and cluster sizes change.

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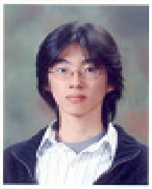
## 저자소개



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