Efficient USN Routing Protocol using Sub-Clustering

Su-Hyung Jeong, Hae-Young Yoo

Abstract— The existing routing protocols in USN environment, PEGASIS is more efficient than LEACH, which is a hierarchical routing protocol, for network configuration based on power consumption. Despite its merit that it can reduce energy consumption per node, however, the PEGASIS protocol also has a weakness that it is less responsive to frequent changes that occur in the configuration of sensor network due to BS nodes that keep changing, which is a typical characteristic of the sensor network. To address this problem, this paper proposes to select sub-cluster heads and have them serve as intermediate nodes. This paper presents and analyses that this method can resolve the aforementioned problem of the PEGASIS algorithm.

Index Terms—USN Routing, Routing Protocol, Sensor Network.

I. INTRODUCTION

Various algorithms have been suggested for efficient routing in the USN (Ubiquitous Sensor Network) environment and they are categorized as flat, hierarchical and location-based methods. Of the existing routing protocols, LEACH (Low Energy Adaptive Clustering Hierarchy) protocol, which is a hierarchical routing method, has been frequently quoted. Also, PEGASIS (Power-Efficient Gathering in Sensor Information Systems), which was introduced as a way to address the energy consumption problem with the LEACH protocol, has attracted attention from a lot of researchers as a complementary alternative to LEACH, resolving its energy consumption issue.

The PEGASIS protocol, however, tends to be incapable of solving issues with the fluctuations of the USN configuration caused by frequent changes in the Base Stations (BS). To solve this problem, this paper proposes a protocol that can transmit data using the PEGASIS chain method after selecting the BS for each sub cluster based on the volume of residual energy per node. This paper covers the following contents; a summary of the existing USN routing algorithm methods and an analysis of the weaknesses of the PEGASIS routing protocol in Chapter 2, the efficient USN routing protocol that is proposed in this paper in Chapter 3, the results of NS-2 simulations used to test our proposed protocol and its effect assessment in Chapter 4, and an analysis of the proposed routing protocol and future research plans in the final chapter.

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II. RELATED RESEARCHES

II-I. Existing USN Routing Methods

II-I-I. Categorization of USN Routing Protocols

The existing routing methods can be largely categorized into the following three protocols as shown in Table 1.

Table 1. Categorization of the Existing USN Routing Protocols

Category	Discription
Flat Routing Protocol	- A routing method based on flooding using flat concept - Difficult to have a practical application because nodes, unlike Ad-hoc, lack the ability to form a self-grown network under the USN environment [4].
Hierarchical Routing Protocol	- A routing method that forms a small network group (i.e. cluster) based on near distance before collecting data, which are transmitted to the BS node and then forwarded to SINK nodes [3]. - Using the BS as a medium for data transmission reduces the volume of overlapping data that get sent to SINK nodes redundantly.
Location-based Routing Protocol	- A routing method that forms a network based on the location information of nodes [6]. - Nodes do not have sufficient memory capacity required to store the location information.

In addition to the above methods, there exist about 20 other USN routing protocols, which can be categorized into studies focused on energy efficiency and studies focused on data collection. Of the existing USN routing protocols, this paper looks into LEACH, LEACH-C and PEAGASIS, which are some of the most common examples of the hierarchical method that our research refers to.

II-II. LEACH

When a multiple number of nodes transmit data to SINK nodes, the adjacent nodes are bound to receive a lot of data traffic due to the structural nature of the sensor network, which makes them consume more energy compared to those nodes located in other areas. The LEACH protocol is a method that utilizes a sub cluster configuration method designed to maximize the network lifespan by equalizing energy consumption among nodes in the USN environment [1].

As shown in Fig 1, in the LEACH protocol, all nodes within a cluster, after a sub network group (cluster) is formed, transmit data only to the Base Station (BS) and the BS then forwards the data to SINK nodes.

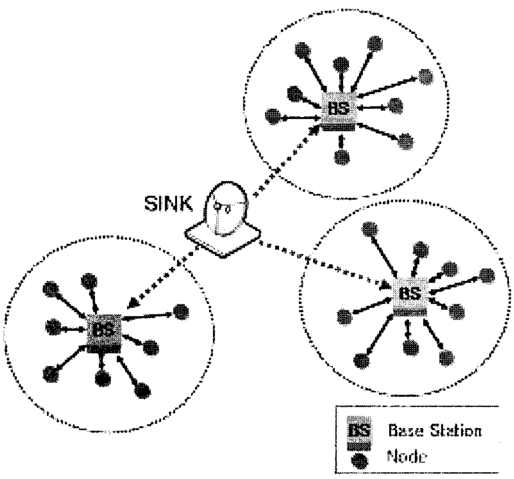

Fig 1. LEACH

II-III. LEACH-C

The LEACH protocol, however, is expected to consume a lot of energy to directly transmit data from the BS to the SINK and lacks adaptability and flexibility when the size of network expands. LEACH-C protocol was introduced in response to such problems and the idea behind it is to sub divide a cluster when collecting data [5].

For the LEACH-C protocol, an additional BS node, which will serve as the head of a sub-cluster, is required to manage each cluster head as shown in Fig 2.

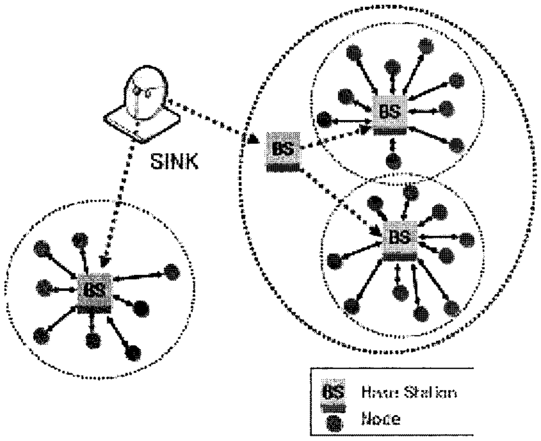

Fig 2. LEACH-C

II-IV. PEGASIS

One of the issues with LEACH or LEACH-C is that it requires time and efforts to form clusters initially. Also, all nodes consume the same amount of electricity. The PEGASIS protocol was introduced to reduce the amount of electricity consumption by nodes in a cluster. In the PEGASIS protocol, each node creates a chain with adjacent nodes before transmitting data and Fig 3 demonstrates how the PEGASIS protocol works.

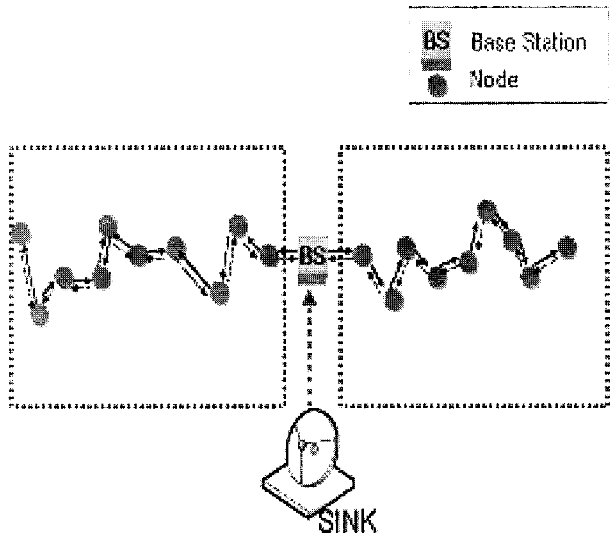

Fig 3. PEGASIS

III. PROPOSED SYSTEM

Among various USN routing protocols, we believe that the hierarchical routing algorithm is logically valid. Thus, this paper analyzes the weaknesses of the PEGASIS protocol and suggests solutions.

III-I. PEGASIS Weakness Analysis

Despite its merit that it can significantly reduce the energy consumption of nodes, the PEGASIS protocol has three major weaknesses that can arise in the process of creating a network.

Table 2. Weaknesses of PEGASIS

Weakness	Description
Energy Information	When forming a network, node chains may need to be recreated because each node's residual energy cannot be measured.
Delay	Greedy algorithm used to determine the added routing weight for nodes may cause a delay.
Bottleneck	Both clusters located on the left and right sides of a BS node may request data transmission simultaneously at the same time.

III-II. Proposed System

In this paper, we propose an efficient USN routing protocol that adopts the web configuration method of the PEGASIS protocol and applies a clustering method, which makes it possible to reduce energy consumption and eliminate difficulties associated with web configuration.

For this, we present solutions to the aforementioned problems with the PEGASIS protocol one by one. To resolve the first weakness, which was the inability to collect information on the amount of residual energy, we propose a sub clustering method that gives considerations to the energy level of head nodes.

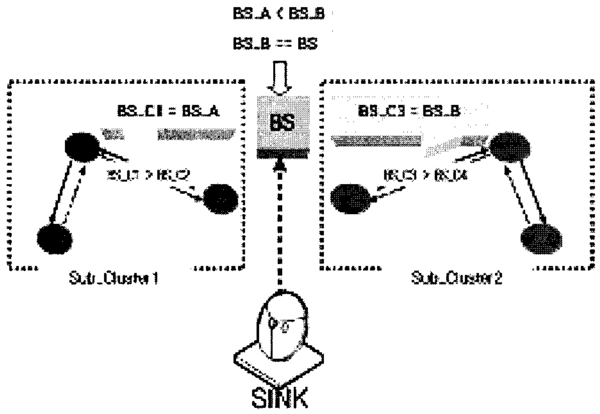

Fig 4. Proposed System – Selecting sub-clusters based on energy information

When nodes transmit data using a greedy algorithm, added weight is calculated before determining which node transmits the data, which causes the second problem listed above. As a solution to this problem, the following formula can be used to determine a node that serves as the BS per round when selecting the head node for a cluster.

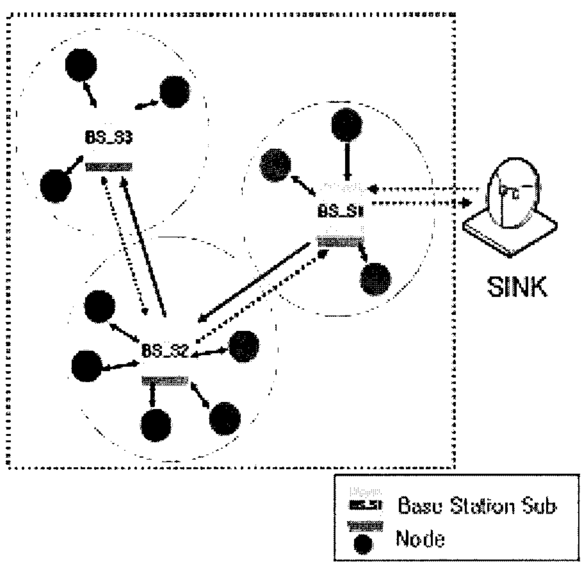

Fig 5. Proposed System – Creating BS-Chain in a sub-cluster

However, it is also possible that our method may create overhead if the size of network expands or frequently fluctuates in the process of selecting the BS node. As for the bottleneck problem, it is naturally solved by applying our sub-clustering method. We will elaborate on this in more detail in the following chapter.

III-III. Operation Procedures for the Proposed System

Following is the overall process of how our proposed system operates.

1) Request information gathering on nodes by broadcasting SINK.
2) Select the initial BS by setting the node located in the shortest path based on the distance between SINK and nodes.
3) Select the BS for each sub-cluster based on the volume of residual energy.
4) Create sub-clusters.
5) Create BS-Chains through sub-cluster headers.
6) Collect data by each node and transmit the data through the BS-chains.

As described in the above list, our system selects which nodes will be used as the BS nodes when creating chains in the network. Once selected, each BS is assumed to have the maximum of 3 to 5 children nodes and chains are formed in each cluster using the greedy algorithm. Lastly, expand chains into clusters that are created and have the children nodes create chains in the clusters. One of the problems with the PEGASIS protocol is that chains get destroyed and our method can resolve this issue. Also, it can significantly reduce overhead in the overall system caused by frequent changes to the BS by taking the residual energy level into account when selecting the BS. Our routing protocol reduces time delays that occur when creating chains compared to the existing PEGASIS routing protocol and resolve problems associated with frequent changes to the BS by measuring the residual energy volume when selecting the BS.

IV. EFFECT ANALYSIS AND ASSESSMENT

To simulate our USN routing protocol that we propose in this paper, we assumed a 50m*50m field where 100 nodes are sporadically distributed using NS-2 simulator to create sub-clusters. The simulation scenario used in this paper is as follows.

First, we assumed a sub cluster can hold three or five nodes when clustering. Then, we measured the percentage of node death per round for each sub cluster. The results of this simulation are shown in Fig 6.

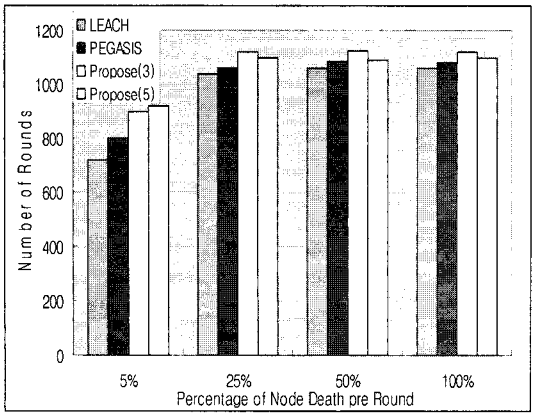

Fig 6. Percentage of Node Death per Round

As a next step, we ran a simulation scenario to measure the maximum lifespan of the last node which allows us to measure the ability to form networks by measuring the duration of time until the last node dies. Fig 7 displays the outcome of this simulation.

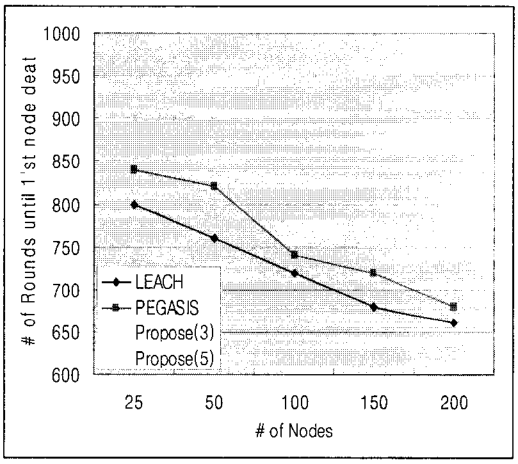

Fig 7. Network Lifetime

V. CONCLUSION

In this paper, we propose a sub-clustering method as a complementary alternative to the weaknesses of the existing PEGASIS routing protocol and used NS-2 simulator for testing.

Compared to the PEGASIS protocol, our system extends the number of rounds by 12% on average according to our research based on the duration of time until the first node dies. When comparing our system with the existing PEGASIS protocol where clusters are formed without any considerations to the residual energy of nodes, the difference is quite significant. Also, we were able to reduce the delay time caused by the greedy algorithm and we believe it will be able to prevent overhead that occurs in each node. Next step is to identify the most efficient and optimal number of nodes for a sub cluster through continued experiments and an analysis of its interoperability with the recently-proposed routing algorithms also need to follow.

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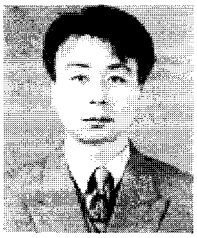

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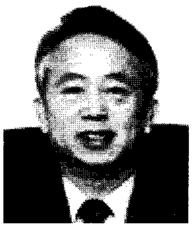

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