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Enhanced Self-Organization Clustering in Mobile Wireless Sensor Networks

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Abstract. When the sensor field is too large in self-organization clustering, energy inefficiency may result when cluster-heads broadcast an Advertisement Message over the sensor field area. Limiting the transmission range of the Advertisement Message is a requirement in this case. Detrimentally, when the transmission range is limited, Advertisement Message non-receiving nodes can be generated due to self-organization clustering. In this paper, we analyze the number of non-receiving nodes in relation to the transmission range when self-organization clustering protocols are used in mobile environments and propose a Two-Tier Clustering method. Two-Tier Clustering evenly distributes cluster-head nodes over the network field and prevents any cluster-head clumping generated by self-organization clustering. Accordingly, our Two-Tier Clustering Method can reduce the number of non-receiving nodes that result when the transmission range is controlled.

Keywords: transmission range, Advertisement Message, Two-Tier Clustering, energy efficiency, non-receiving nodes.

1 Introduction

Cluster-based routing protocols are one of the methods used to save transmission energy and increase sensor node efficiency. Cluster-based routing protocols configure clusters with neighboring nodes through specific rules to select a head node in that cluster which then transmits the data received from each sensor node to the base station. By using cluster-based routing protocols, each sensor node saves transmission energy since it does not send data to the base-station individually, resulting in increased life span for each individual sensor node. Many studies of cluster-based routing protocols suggest various head node election methods [1-7].

Self-organization clustering proposed in LEACH (Low Energy Adaptive Clustering Hierarchy) has been based on several studies of energy efficiency [6] [8-10]. In MWSNs, it is difficult to adapt self-organization clustering methods without some modification. Because LEACH assumes a sensor field size of 50m X 50m, it is possible to broadcast the Advertisement Message for clustering throughout the sensor field. However, the sensor fields in MWSNs are often larger than those in WSNs. When the sensor field is too large, energy inefficiency may result when cluster-heads broadcast the Advertisement Message over the sensor field. Limiting the transmission

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range of the Advertisement Message is a requirement in this case. Detrimentally, when the transmission range is limited Advertisement Message non-receiving nodes can be generated due to self-organization clustering.

In this paper, we analyze the number of non-receiving nodes in relation to the transmission range when self-organization clustering protocols are used in mobile environments. In addition, we suggest a Two-Tier Clustering (TTC) scheme to reduce the number of non-receiving nodes. The existing self-organization clustering protocols achieve clustering in one-step, whereas our proposed method is a two-step process. TTC evenly distributes cluster-head nodes over the network field and prevents any cluster-head clumping generated by self-organization clustering. TTC can reduce the number of nodes which do not belong to clusters compared with existing self-organization clustering protocols for any arbitrary R. Consequently, our TTC protocol will result in reduced data loss, increased energy efficiency, and enhanced sensor network field robustness by reducing the number of Advertisement Message non-receiving nodes.

2 Analysis of Non-receiving Nodes for Advertisement Message

In self-organization clustering, each node generates a random number independently. The nodes that become cluster-heads broadcast an Advertisement Message to the other nodes. When the transmission range for broadcasting an Advertisement Message is limited to a radius of R, non-receiving nodes can be generated in the network field. When a node does not receive any Advertisement Message from any cluster-head nodes, it loses a chance to send its data.

We can calculate the number of non-receiving Advertisement Message nodes N_{non-r} in a sensor network. Assume N sensors are distributed randomly in a network field with the size of F that is monitored. θ is the threshold to become a head node.

$$N_{non-r} = (1-\theta)^{\lambda} N. \qquad (1)$$

We can calculate the average number of nodes λ in relation to R as follows

$$\lambda = \frac{N\pi R^2}{F}. \qquad (2)$$

From formula (1), a graph in Figure 1 shows the number of non-receiving nodes in relation to the transmission radius (R) in a 1000mX1000m sensor field with several 1000 node topologies that are randomly distributed. Let $p = 0.05$. p is the ratio between the number of cluster-heads and the total number of sensor nodes,

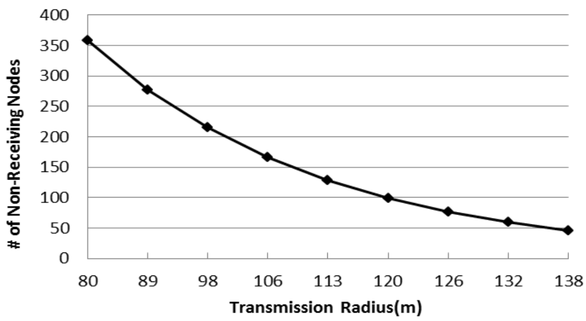

Fig. 1. Analysis of Number of Non-Receiving Nodes.

As in Figure 1, the smaller the transmission radius, the larger the number of non-receiving nodes.

3 Two-Tier Clustering Scheme

In self-organization clustering, if a non-cluster-head node does not receive any Advertisement Message, it cannot belong to any cluster and successfully transfer its sensing data through a cluster-head to the base station.

In existing self-organization clustering protocols, clustering is performed at the set-up phase: consisting of head election, transmission of an Advertisement Message and the join-cluster decision of non-head nodes. The basic idea of TTC is to perform the set-up phase twice to reduce the number of non-receiving nodes that are excluded from clusters.

In TTC, let p' as a ratio of cluster-head nodes in the first step and p'' as a ratio of cluster- head nodes in the second step. The entire ratio of cluster-head nodes p will be:

$$p = p' + p'' \quad . \tag{3}$$

For the first step in clustering, each node generates a random number between 0 and 1 and compares that number to the threshold θ' calculated by a predetermined ratio of cluster-head nodes and the number of transmission rounds.

$$\theta' = \frac{p'}{1-p'(r \bmod 1/p')} \quad . \tag{4}$$

The nodes which have not received any Advertisement Message in the first step perform the second step of clustering. N' denotes a set of nodes which have not been included in any clusters at the first step.

To generate $p'' \cdot N$ cluster-heads among the nodes in set N', the threshold θ'' is :

$$\theta'' = \frac{p''}{(1-\theta')^{\lambda}} \quad (5)$$

$(1-\theta')^{\lambda}$ is the ratio of non-receiving nodes after the first step in clustering. Each non-receiving node from the first step generates a random number and compares it with the threshold θ'' for the second step. If the generated random value is less than θ'', then the node becomes a cluster-head node. Elected cluster-head nodes broadcast an Advertisement Message to the rest of the nodes within a radius of (R). In the second step, each non-cluster-head node sends a response message to the cluster-head node after it decides which cluster it will belong to by repeating the same process as in the first step. The nodes that have received an Advertisement Message from several cluster-head nodes respond to the head node that has broadcast the strongest Advertisement Message signal.

4 Performance Evaluation

To evaluate the performance of our TTC, we simulate LEACH-mobile and MBC together. We assume 1000 nodes are scattered randomly in a 1000m X 1000m sensor field. The total percentage of cluster-head nodes is 5%. In TTC, we suppose the percentage of cluster-head nodes as 4% in the first step of cluster head node election and 1% in the second step in order to generate the same percentage of cluster-head nodes as in LEACH-Mobile and MBC.

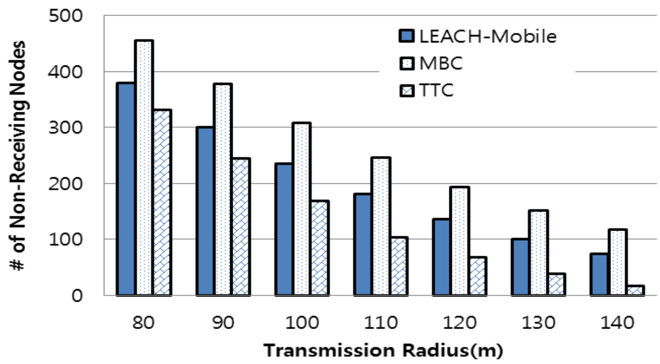

Fig. 2. Comparison of Number of Non-Receiving Node

From the results of this simulation, TTC reduces the number of non-receiving nodes by more than 12 % compared with LEACH-Mobile and achieves a 27% reduction when compared with MBC. As the transmission radius increases, the number of non-receiving nodes is reduced. In our proposed strategy, when the transmission radius is 140m, a more than 75% reduction in the number of non-receiving nodes is achieved compared with LEACH-mobile and an 84% reduction is achieved compared with MBC.

5 Conclusion

When the sensor field is too large, energy inefficiency may result when cluster-heads broadcast an Advertisement Message throughout the sensor field. When the transmission range for broadcasting an Advertisement Message is limited to a radius of R, non-receiving nodes can be generated in the network field. In this paper, we analyzed the number of non-receiving nodes in relation to transmission range when we use self-organization clustering in mobile environments. In addition, we suggested our TTC in order to reduce the number of non-receiving nodes created in a cluster field. To evaluate the proposed method, we compared the number of non-receiving nodes in TTC with those in LEACH-Mobile and MBC through simulation, and found that our TTC reduced the number of non-receiving nodes excluded from clusters. In other words, TTC reduced data loss and increased energy efficiency according to the adaptive distribution of cluster-head nodes throughout a network field of any given radius.

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