모바일 에드-혹 센서 네트워크를 위한 에너지 효율적 라우팅 기법 개발

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Development of Energy Efficiency Routing Technique for Mobile Ad-hoc Sensor Network

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Abstract

The development of USN(Ubiquitous Sensor Network) technology is creating numerous application areas. Although a network configuration with fixed sensors was the norm in the past, the coexistence of mobile and fixed sensor nodes is a new trend. Fixed sensor networks focused on the energy efficiency of nodes, but the latest studies consider guaranteeing the mobility of nodes and maintaining their connectivity, while remaining energy efficient at the same time. This paper proposes a routing protocol for a mobile ad-hoc sensor network that improves the mobility, connectivity and energy efficiency of nodes while allowing for the management and maintenance of a large number of nodes even in a complex communication environment where mobile and fixed nodes coexist. An algorithm for multi-hop multi-paths, a technique for topology reconfiguration by node movement prediction and vibration sensors, path setting for a large number of nodes, and efficient data transfer technology have been introduced to implement the modified LEAHC-AOMDV protocol. Furthermore, the excellence of this protocol was verified through a comparative experiment with the conventional LEACH protocol.

1. Introduction

USNs generally consisted of fixed sensors, but the miniaturization of sensors has brought about mobile sensor nodes. As a result, instead of focusing only on the energy efficiency of sensors, the latest studies have to address complex issues such as ensuring the mobility and connectivity of nodes while considering energy efficiency as well. The results of these studies can be applied to various areas through combining with other technologies such as environmental pollution monitoring, traffic flow monitoring, freight tracking, and nano-technology.

The core issues of these two lines of studies are different: Fixed USN is focused on the management of a large number of nodes and energy efficiency whereas MANET is focused on the mobility and connectivity of nodes.

This paper proposes a routing protocol that combines the characteristics of the protocols used in fixed USN and MANET in order to efficiently guarantee the management of a large number of sensor nodes, energy efficiency, and the mobility and connectivity of nodes. The sensor network protocol LEACH was used as the basis and the features of the MANET protocol AOMDV were incorporated. This method enabled rapid network convergence and minimized packet flooding by detecting node movement probability beforehand through a mathematical model and hardware technique.

In this paper, Chapter 1 gives an introduction to the study and Chapter 2 briefly reviews the related studies. Chapter 3 describes the modified LEACH-AOMDV protocol and technique, and Chapter 4 describes the results of the comparative experiment between the conventional LEACH protocol and the proposed protocol. Lastly, Chapter 5 provides the conclusion.

2. Related Work

2.1 Flat routing protocols [1]

In flat routing protocols, no effort is made to organize the network or its traffic. All routers are considered sitting on a flat geometric plane, and the best route to a destination is discovered hop by hop by any path. Unlike traditional wired networks, in which each node is identified by a unique address, sensor networks are data centric, i.e., the interest is in "*what* is the data" rather than "*where* is the data," so they do not generally require routing between specific nodes. Two well-known flat routing protocols are described below.

2.2 Clustering techniques [2]

A cluster is composed of a cluster head (CH) and other nodes that are within the direct transmission range of the CH (i.e., distance by one hop). In each cluster, the nodes that are distant from other cluster heads by 1 hop (i.e., the nodes belong to more than one cluster as a non-cluster-head) are called gateway nodes. To carry out flooding for route discovery using clusters, clustering that organizes a sensor network into clusters must be previously performed [3]-[5].

3. Proposed Routing Protocol

Since a great number of nodes are deployed in a USN, preserving node detection, path selection, and network connectivity are challenging issues. One of the most important issues in wireless ad hoc networks is to minimize the "flooding packet."

3.1. Multi-hop algorithm for Topology configuration of LEACH-AOMDV Protocol [6]

A multi-hop configuration is required for preserving the connectivity of moving nodes. To address this issue, the proposed protocol adds a few modules to the conventional LEACH protocol. Multi-hop configuration facilities provided by the LEACH routing system implemented in TinyOS 1.x [7] are used, and additional modules are also implemented to facilitate routing. In particular, requests for duplicate routes are stored by applying AOMDV (Ad hoc On-demand Multipath Distance Vector)[8]-[11], a duplicate route selection technique used in mobile ad hoc networks, to the LEACH protocol.

3.2. Module for reducing Topology reconfiguration time based on node movement estimation and vibration sensors [7],[12]

The modified LEACH-AOMDV protocol can predict topology changes based on the mathematical model that estimates node movement. In the proposed protocol, the possibility of node movement is predicted in advance based on the probability theory and event triggering, so that the network can

react more promptly to its topology change caused by node movement. The possibility of a node falling out of the communication range is calculated using a formula that considers collectively the waiting time of mobile or sensor nodes, the node's location, movement direction, movement speed, and the residual energy.

In addition, the technique to perform the operations "Join" and "Leave" for a sensor node based on a vibration sensor is introduced for energy conservation. The principal idea is including a vibration sensor in a node to figure out whether or not the node is stationary. If an event indicating the node is on the move is generated, the network topology is reconfigured immediately without waiting for the timeout signal. When there is no event regarding node movement, nodes are placed in Sleep mode to save power.

3.3. An efficient path selection and data transmission technique for a large number of nodes [13]

Within a grid, there might be more than one cluster. Once the grids and clusters are established in a network area, an efficient communication path selection is possible with the aid of the grids. The conventional grid technique allows communication only in a vertical or horizontal direction from the grid cell in which an event of interest occurs. Under such constraints, an inefficient path, as shown in A-path of Figure 1, is selected by establishing a reverse path from the sink to the source. Instead of letting communication start in a vertical or horizontal direction from a grid cell and then forming a reverse path, using node IDs that are stored in a node cache when communication starts for the first time makes it possible to find a shorter and more efficient path, as shown in B-path of Figure 1.

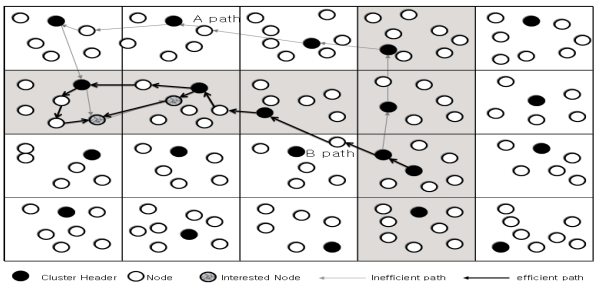

Figure 1. Inefficient or efficient transmit path

4. Experiments

4.1. Experiment environment

The number of nodes used to measure the time taken to configure a network is 200, and the number of nodes used to measure the time taken to reconfigure the network topology is 50.

4.2. Comparison of network configuration time

In this experiment, network configuration times of the proposed protocol and of the conventional LEACH protocol are measured by increasing the number of nodes.

4.3. Comparison of network topology reconfiguration time

Network topology reconfiguration time means the time taken from the beginning of reconfiguring the network topology owing to the changes of node location, till the beginning of the normal operation of the reconfigured network. Reconfiguration is launched when nodes, including cluster heads, move out of the communication range, or when cluster heads receive an event message that advertises the node's movement. The events advertising node movement are generated based on the vibration sensor attached to a node, or on the mathematical estimation model of node movement. On the average, the reconfiguration time of the proposed protocol is faster than the convention LEACH protocol by 23.069 seconds.

4.4. Comparison of routing overhead

Routing overheads of the conventional LEACH protocol and the LEACH-AOMDV protocol are measured by accumulating the created control packets and comparing the number of the accumulated packets. In the experiment, the number of created control packets is measured by randomly transmitting 50 packets over the network, consisting of 200 nodes. In the proposed protocol, the number of the created control packets increases by 14.3% (511 more control packets are created), as compared to the conventional LEACH protocol.

4.5. Comparison of remaining node counts

For comparative experiments of the remaining node counts, the total number of nodes was fixed at 200, and packets of the same size were continuously passed through the network. Then, the number of nodes that had remaining energy over a threshold for a predefined unit time was counted. Because the proposed protocol had a high routing overhead, it could be inferred from the experimental results that energy consumption for transmission was not greatly saved in comparison to the conventional LEACH protocol. However, the proposed protocol had a greater number of nodes that had remaining energy over the threshold than LEACH.

5. Conclusion

This paper has presented a routing protocol that is a variant of the conventional LEACH protocol. That is, the conventional LEACH protocol is modified to be more suitable to a network environment where real-time monitoring of a larger number of moving sensor nodes is required, such as pollution surveillance applications, habitat monitoring applications, and traffic control.

The modified LEACH-AOMDV protocol offers reactive routing by predicting a situation in which network topology change is required, based on the mathematical estimation model of node movement and vibration sensors attached to the nodes that are used to sense their movement. Furthermore, additional modules used to perform efficient node detection and path selection for a large number of mobile nodes are implemented in the LEACH-AOMDV protocol.

The experiments have been performed to evaluate the performance of the proposed protocol in terms of four factors. Overall, the modified LEACH-AOMDV protocol proposed in this paper can perform better than the conventional LEACH protocol in a network environment in which real-time node monitoring, mobility of sensor nodes, network connectivity, and energy efficiency should be collectively taken into account.

For future work, the algorithms and techniques implemented in the proposed protocol will be optimized in order to minimize flooding packets and routing related packets, which in turn lead to reduced routing overhead.

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