Design of Stochastic Movement Model Considering Sensor Node Reliability and Energy Efficiency

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Abstract

Wireless Sensor Network (WSN) field is mainly studied to monitor and characterize large-scale physical environments to track various environmental or physical conditions, such as temperature, pressure, wind speed and humidity. WSN can be used in various applications such as wild surveillance, military target tracking and monitoring, dangerous environmental exploration and natural disaster relief. We design probabilistic mobile models that apply to mobile ad hoc network mobile environments. A probabilistic shift model proposed by dividing the number of moving nodes and the distance of travel into two categories to express node movement characteristics. The proposed model of movement through simulation was compared with the existing random movement model, ensuring that the width and variation rate of the first node node node (FND) was stable regardless of the node movement rate. In addition, when the proposed mobile model is applied to the routing protocol, the superiority of network life can be verified from measured FND values. We overcame the limitations of the existing random movement model, showing excellent characteristics in terms of energy efficiency and stable in terms of changes in node movement.

Keywords: Magnet, Mobility Model (MM), First Node Dead (FND), Mobile characteristics, Random model, Energy-consumption

1. Introduction

Sensors connect reality with the digital world by showing real world phenomena. The physical environment consists of light, temperature, motion, seismic waves, and a variety of other information. To better understand the environment, multiple information needs to be collected, and WSN is an easy-to-deploy system to understand this rich information. Currently, a wireless sensor network consisting of dozens and hundreds of sensor nodes can already observe large geographic areas to model and predict the environment, collect
information using air/water pollution, flooding and vibration sensors, and control the use of water, fertilizer and pesticides to improve the condition and crop conditions.

A wireless sensor network consists of spatially scattered sensors that observe the physical external environment and transmit measured data over the network to the central node (Cluster Head, CH) or Base-Station (BS). Recent wireless sensor networks support two-way communication, allowing nodes to transmit information observed to central nodes or base stations, as well as control the behavior of sensors at base stations. The wireless sensor network consists of several to hundreds or thousands of nodes, each connected to one or several sensors. The sensor node consists of a wireless transceiver connected to an internal antenna or an external antenna, a micro controller, an electronic circuit for sensors and interfacing, and a battery. The size and cost of sensor nodes are variable and, depending on their complexity, prices range from the size of apple boxes to the size of grain grains, from tens to hundreds of dollars. Constraints in size and cost of sensor nodes in use result in constraints on resources such as energy, memory, computational speed, and communication bandwidth. The topology of sensor networks ranges from simple star networks to complex multi-hop wireless mesh networks. The method of propagation between hops in a network can be determined based on routing protocols [1-5]. With the development of sensing technology, MEMS technology, low-power electronic engineering technology and low-power RF technology, wireless sensor network is now used in almost all areas. Each application network has different requirements depending on its intended use. Wireless sensor networks must have the unique capabilities required to meet the requirements of applications and to design successful wireless sensor networks. The need for these functions includes a variety of technical problems that are hard to find in other wireless networks [6].

Many studies have been attempted to understand mobility because the performance of routing protocols is greatly improved if the movement pattern of nodes in the network can be predicted [7-8]. Typical random mobility models typically generate random movement patterns to model node mobility. The simplest node-movement model is simple to implement and expresses the moving characteristics of individual nodes. The mobile models proposed in the mobile ad hoc network are approached from various perspectives and provide many ways to achieve various goals [9-10]. Adoption of a mobility model suitable for utilization purposes is key to important success in designing routing protocols for mobile ad hoc networks. In simulations of mobile network protocols, the choice of mobile models can significantly change the performance results of network protocols. To validate the new protocol, it is essential to use a mobile model that accurately represents the mobile node characteristics to be used by the protocol. The random movement model, currently the most widely used, simple and easy-to-implementation model, is a model of node movement only as a random attribute of a certain speed range. Simple random attributes alone are not suitable for representing node movement characteristics. WSN and mobile ad hoc network are the main purpose of observing the actual external physical environment. Changes in the external physical environment observed by the user will have unique statistical characteristics of movement. In the moving model, the moving characteristics of individual nodes can be expressed in random attributes. In addition, the full node movement characteristics should be considered simultaneously in the mobile model. Based on the statistical interpretation of sensor field movement change, the stochastic movement model with excellent robustness and energy efficiency characteristics in node movement environment is designed in this paper. Through experimentation, the proposed Stochastic movement model is compared with the representative random movement model to verify excellence.

2. Related Works

2.1 Wireless Sensor Networks
A wireless sensor network is a configuration of nodes that communicate with each other over a wireless area. We focus here on the energy efficiency problem of radio signal propagation. The classification of these wireless sensor networks depends on a variety of factors, including application-level objectives, number of communication nodes, level of node mobility, and resources available on each node. Among the various purposes of utilization, related studies are introduced focusing on wireless sensor network and mobile ad-hoc network considering energy efficiency and node mobility.

Routing is a major problem in all networks with finite resources. The routing protocol is responsible for the search and maintenance of routes in the network. The network architecture greatly affects the routing strategy used and its advantages and disadvantages. Due to various restrictions on wireless networks, routing protocols used in these networks are also subject to several restrictions. Many studies have been carried out in this field and two types of topology structures, mainly flat topologies and hierarchical topologies, have been proposed. In a plane structure, all nodes in the network are on an equal level, have the same routing functions, and are simple and efficient in small networks. The problem, however, is that as the network grows, the amount of routing information increases rapidly and it takes a long time for routing information to reach the final node. For large networks, cluster-based hierarchical routing can be used to solve problems. In hierarchical routing, nodes in the network are dynamically organized by being grouped into areas called clusters, and the data in clusters is eventually collected by base stations.

### 2.2 Mobile Ad-hoc NETwork, MANET

The mobile ad hoc network is a distributed self-configuring network consisting of multiple mobile nodes, each of which acts as a router, one of the communication facilities. A mobile ad hoc network is a particular type of network that has limitations such as energy consumption, network bandwidth, number of mobile nodes, and topology changes. Clustering of mobile ad hoc networks has many advantages [11]. Clustering of mobile ad hoc networks makes routing easier and helps manage the network by reducing energy consumption. Mobile ad hoc networks can reduce network overhead by using less temporary storage during routing. In a mobile ad hoc network, clustering techniques are a factor that makes a network powerful because communication failures within a cluster affect only a particular cluster, not the entire network. In addition, clustering can also improve throughput, spatial reuse and scalability.

### 2.3 Mobile model in wireless sensor network

Various measures are being studied to extend network life and improve performance in a new deployment environment following the movement and movement of wireless sensor nodes [12]. Some of the proposed models also use one moving node to collect measured information from static sensor nodes. In another mobile model, the mobile model that uses one or more moving nodes in the network falls into a completely different category. Models with multiple moving nodes place the moving nodes to obtain the best coverage and connectivity across the entire sensor field area. Mobile ad hoc network mobility models can be classified into two categories: homogenous model and heterogenous model in measurement data centric model. The homogeneity mobility model has a moving node group that uses the same mobility model to move within the network. However, the heterogeneity model has a single moving node that moves according to a particular mobility model within the network. The homogeneity mobility model has a moving node group that uses the same mobility model to move within the network. The heterogeneity model is based on having a single moving node within the network that moves according to a particular mobility model.
3. Proposed Method : Stochastic Movement Model

In many applications of wireless sensor networks, individual nodes are used and required to be mobile as well as static. In addition, efficient energy consumption using energy-limited batteries is an important issue. These requirements are problematic in the design of MAC and routing protocols. This chapter designs a moving model that can accurately describe the situation in which node movement occurs, verifies the stability of the proposed Stochastic movement model, and details the efficient energy management methods.

Organize the general assumptions of sensor field node movement environment for Stochastic movement model proposal, model node movement number and node travel distance in proposed Stochastic movement model. It then describes the fuzzy-based routing algorithm utilizing the proposed mobile model. It also defines the experimental environment and demonstrates the legitimacy and robustness of the proposed Stochastic mobile model by experimenting with existing mobile models and proposed mobile models applied to routing protocols according to the node movement ratio, comparing their performance.

Figure 1 shows the sequence of routing algorithms. In the mobile ad hoc network environment, the proposed Stochastic mobile model is an algorithm that transmits measured data to the final destination BS after clustering by selecting an effective CH after node movement. This section describes the step-by-step process of algorithm based on the proposed Stochastic mobile model.

At the beginning of each round the nodes move, resulting in a new sensor field. The number of nodes moving or the distance moved follows a specific probability distribution as described in the previous section. After the sensor nodes have finished moving, BS calculates the moving factors of all nodes according to the movement using the movement. Next, BS uses expressions to obtain the residual energy and the local distance of all nodes. These two courses will provide both FIS input variables.
4. Simulation and Results

This section compares the random-way point mobility model (RWPMM) of the mobile sensor network with the semi-probabilistic mobility model (SSMMM) proposed in this paper and the stochastic mobility model (SMM) to verify the robustness and energy efficiency of the proposed model.

RWPMM is a fixed value obtained by multiplying the number of moving nodes by the total number of moving nodes, and the travel distance is set at random. SSMMM is considered a probability variable that the number of moving nodes follows the Poisson distribution, and the travel distance is randomized. Finally, SMM treats the number of moving nodes as a probability variable that follows the Poisson distribution, and the distance traveled is considered a random variable that moves freely within the range of distances where smooth transmission and reception are possible. For each moving model, the number of moving nodes and the travel distance conditions are summarized in Table 1.

<table>
<thead>
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<th>Table 1. Mobility model</th>
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<tr>
<td><strong>RWPMM</strong></td>
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<tr>
<td>Movement</td>
</tr>
<tr>
<td>Node Number</td>
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<td>Movement</td>
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<td>Distance</td>
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RWPMM has a densitist problem. That is, after the round, the result is that the sensor nodes are centered, ignoring the assumption that the nodes are evenly distributed in the sensor field. To solve these problems, SSMM and SMM are proposed. To this end, the proposed SSMMM and SMM confirm node placement in the 10th, 50th and 100th rounds. Table 2 shows the node position in round 1, round 50 and round 100 with a sensor field size of 200×200 and a sensor node of 100 with 10% node movement. In the 100 rounds of the RWPMM, it can be seen that the placement of the sensor field interface is genital, and that the node density is relatively high near the center of the circled field. If the round is more advanced, it will be more concentrated in the center. RWPMM can confirm that there is a density wave problem.
5. Conclusions

We designed two Stochastic mobile models to express the environmental changes caused by node movement. The first proposed move model, Semi-stochastic move model, treated the number of node movements as a probability variable along the Poisson distribution. The range of distances a node can travel to one round was limited to smooth coverage based on the radio system connection margin (LinkMargin) in accordance with the Zigbee IEEE 802.15.4 radio specification. The Stochastic moving model proposed in this paper has been confirmed to be stable regardless of node movement ratio because of its narrower variation than the random movement model for node movement. In addition, the fuzzy-based routing protocol using the mobile factors of the proposed Stochastic mobile model could also be found to have better energy efficiency performance than the existing LEACH-mobile protocol. When designing routing algorithms in mobile ad hoc networks where mobile nodes exist, the proposed Stochastic movement model would allow for simultaneous consideration of the overall moving characteristics as well as the individual characteristics of mobile sensor fields. In addition, when developing clustering-based routing algorithms, applying the Stochastic movement model will also help design protocols that are strong in changing node movements but energy efficient.
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