Chapter 27
A Grid-Based Localization Technique for Forest Fire Surveillance in Wireless Sensor Networks: Design, Analysis, and Experiment

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ABSTRACT

This chapter presents a novel grid-based localization technique dedicated for forest fire surveillance systems. The proposed technique estimates the location of sensor node based on the past and current set of hop-count values, which are to be collected through the anchor nodes' broadcast. The authors' algorithm incorporates two salient features, grid-based output and event-triggering mechanism, in order to improve the accuracy while reducing the power consumption. The estimated computational complexity of the proposed algorithm is $O(N_a)$ where N_a is the number of anchor nodes. Through computer simulation, results showed that the proposed algorithm shows that the probability to localize a sensor node within a small region is more than 60%. Furthermore, the algorithm was implemented and tested with a set of Crossbow sensors. Experimental results demonstrated the high feasibility of good performance with low power consumption with the proposed technique.

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INTRODUCTION

Wireless Sensor Networks (WSNs) provide unprecedented opportunities for monitoring areas of interests such as chemical factory, homes and offices, with low-cost, low-power and multi-functional sensors. As such, WSNs attract considerable amount of attention from researchers all over the world. Usually one should use a large number of sensor nodes to deploy a WSN because these sensors generally are small in size and can only communicate within short distances. Information can be collected from a WSN node through the base station. However, the collected information would be meaningless if we could not determine the location of a WSN node. Consequently, fast, efficient and low-cost localization techniques are highly desirable for WSNs applications.

The key idea of WSN localization is to allow some sensor nodes to know their own location at all time. Such nodes, usually called *anchors*, may be equipped with Global Positioning System (GPS) or be fixedly placed at pre-determined positions with known coordinates. For the sake of low cost, most sensor nodes do not know their locations. These nodes with unknown location information are called *non-anchor* nodes. Interestingly, their locations can be estimated by applying WSN localization techniques (Mao, Fidan, & Anderson, 2007).

Localization techniques in WSNs are classified into two groups: range-based and range-free techniques. Range-based techniques use sophisticated hardware to conduct complex measurements on distance or angle of signal arrival to obtain location estimates. Typical range-based localization schemes includes those using received signal strength (RSS) (Bahl & Padmanabhan, 2000), time of arrival (TOA) (Ward, Jones, & Hopper, 1997), angle of arrival (AOA) (Niculescu & Badri, 2003), and time difference of arrival (TDOA) (Priyantha, Chakraborty, & Balakrishnan, 2000). Noteworthily, range-based localization techniques are applicable only when the non-anchor node of interest is within communication range of the anchor nodes. Due to the expensive hardware requirement, range-based techniques are generally considered as high-cost solutions. Consequently, this shortcoming unfortunately hinders them from being applied for forest fire surveillance, which is normally formed by millions of sensor nodes.

Range-free algorithms estimate the location of a sensor only based on the connectivity between non-anchor nodes and anchors. Three typical existing range-free techniques are the DV-hop (Niculescu & Nath, 2001), Monte-Carlo Localization (MCL) (Hu & Evans, 2004) and Monte-Carlo Box (MCB) (Baggio & Langendoen, 2008) algorithms, which are revisited later. The general principle of these techniques is that localization can be estimated from the proximity constraints, which are defined by a sensor node of interest being in the transmission ranges of other sensor nodes. To the authors' best knowledge; none of aforementioned localization techniques is exclusively designed forest fire surveillance. Consequently, when the existing localization techniques were applied in forest fire surveillance systems, they would inevitably result in certain disadvantages such as high complexity, low efficiency and large power consumption. The reasons are that they normally return an exact point or coordination of the targeted sensor node's location. Thus, the algorithms are complicated in general. However, for forest fire detection, a precise location point may not be needed. In fact, we may need to find out an area of region inside a forest in where the fire is occurred.

This chapter aims to contribute a simple and novel localization technique for forest fire surveillance by monitoring and tracking groups of animals using WSN technology. The proposed technique combines the three existing range-free techniques and improves the accuracy. In brief, we propose to attach sensor nodes to selected animals. Whenever the temperature sensed at these animals' proximity rises beyond a predefined threshold, the localization module in the sensor