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Adaptive Trap Coverage in Mobile Sensor Networks

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Abstract

In this paper, a novel mechanism for adaptive trap coverage in area coverage model by using mobile sensors is proposed. Many applications, such as target detection and tracking, are highly required with the characteristics of trap coverage, especially adjusting the trap size adaptively in terms of sensors movement in mobile sensor networks (MSNs). This paper is to propose an adaptive mechanism for trap coverage relied on the cooperation of the involved mobile sensors to either shrink or expend the trap. The trap exists to incur that the target has predictably vanished and remains undetected. The experimental results show that the adaptive trap coverage can be explored in an efficient way by the energy consumption of sensor movement and the number of data communications among sensors.

Keywords: Mobile Sensor Networks; Target Tracking; Trap Coverage; Wireless Sensor Networks

1. Introduction

A wide variety of applications involving sensors exists in wireless sensor networks (WSNs) for Internet of Things (IoT). Mobile sensor networks are a type of WSNs, in which sensors can perform specific tasks through sensing environments, wireless communications technology, computation, and memory storage. Coverage is one of critical issues in WSNs. Coverage problems are typically categorized into the following three classes: target coverage, barrier coverage, and area coverage[11]. Sensors communicate with each other and perform the data collection and filtering,

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ensuring full monitoring and filtering of the desired region for target coverage. In order to fulfill the complete barrier coverage or area coverage, the coverage problem emerges. The area coverage is thus generally the first and main concern in many applications based on random or rule-based deployment of sensors. A superior system performance in WSNs obviously involves higher hardware costs for the system.

The main challenge of this work is that the trap obviously exists because of the mechanism of trap coverage, in which the target has predictably vanished and remains undetected[2,4,5]. The properties of the trap in the trap coverage mechanism are contrary to the purpose of target tracking and detection. It generates a serious problem for target tracking in MSNs. Hence, this paper proposes a novel coverage model, named adaptive trap coverage. The trap can be shrink or expended to form a smaller or larger trap holes, respectively for different purposes. For example, while a target (intruder) is entering a trap, the mobile sensors can move into the trap to track and monitor the target by shrinking the trap hole. These mobile sensors should keep communication with each other. In contrast to reducing the trap size, expending or enlarging a trap to larger one for some specific purpose can alleviate the burden of monitoring the trap. The extra sensors can be dispatched to cover other traps with larger size. That is, mobile sensors can work together to move toward to larger traps adaptively for balancing the trap sizes among traps in MSNs.

This paper is to address the novel definition of trap coverage so that the trap coverage is more reasonable to alleviate the disadvantage of trap coverage as presented by Balister *et al.*[2]. Although trap coverage with adequate performance can operate effectively for numerous applications, low efficiency is likely for specific applications in WSNs, e.g., detecting and tracking moving objects. The idea mentioned above is that we allow the existence of a trap under the trap coverage mechanism whenever an object moves dynamically into it. It causes the object to vanish and remain undetected in the area covered and weakens the entire performance of sensor deployment MSNs. An adaptive trap coverage mechanism is proposed here for either shrinking or enlarging the trap in order to explore many useful applications. Sensors are moved according to the shrinking and enlarging processes.

The rest of this paper is organized as follows. Section 2 introduces a review of related works regarding coverage issues and the deployment of sensor nodes by using mobile sensors in MSNs. Section 3 presents the network model as well as basic definition and assumptions. Section 4 details Nr_s-trap coverage adjustment based on the mechanism of sensor movement. Section 5 provides the simulation results. Finally, Section 6 offers a conclusion.

2. Related work

Issues on coverage and sensor deployment have been discussed in many studies in WSNs[11]. Their purpose is to propose efficient coverage methods for many applications, e.g., intruder detection, target positioning, and environment monitoring. Below are summarized some related work for coverage in WSNs.

The ROI (region of interest) is covered by all sensors for full large-scale coverage. The k-full coverage that uses a minimum of k-sensors for covering the entire ROI has been detailed in previous studies[1,6,13,14]. Full coverage may evidently lead to high costs for WSN deployment. Regarding trap coverage, Balister *et al.*[2] proposed "d-trap coverage," which is regarded as the alternative scheme for full coverage. Trap coverage permits "holes" to appear in WSNs and exhibits efficient performance with the cost-effective sensor hardware, which defines the trap size and determines the range of the trap coverage based on a mathematical model. The analysis of trap coverage involves examining the density of sensors in the deployment and the quality of trap coverage in WSNs. Li *et al.*[8] proposed a method of trap coverage that fulfills the requirement of network performance in deploying sensors in WSNs with cost-efficient hardware. The disadvantage in previous studies[2,8] has involved using static sensors for deploying sensor networks with trap coverage because all static sensors are stationary, thereby leading to limited performance after sensor deployment.

The novel proposed coverage mechanism, adaptive trap coverage, involves a tradeoff between the hardware cost and system performance based on the method reported by Balister *et al.*[2]. Trap coverage is redefined and target tracking is performed by employing the mobile sensors. Mobile sensors can move adaptively and adjust network topology dynamically at a reduced sensor cost. A trap size d was defined as the longest distance d in the trap, of which the target can travel within the d-trap coverage[2]. It is inappropriate while estimating the area covered using the distance metric in the d-trap coverage. The measure of one dimension in the distance metric is evidently unsuitable for that of two dimensions in the area metric in trap coverage.

Here, we apply the circle-based concept for describing the trap size and shape in trap coverage. At first, the maximum circle of the trap with a *trap radius* Nr_s, where r_s is the sensing range of a sensor and $N \geq 1$ is a real number