Chapter 4

Region Coverage and Protection with Sensors: A Survey

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**ABSTRACT**

Covering an area with sensors has been an active research area in recent years. Coverage problems for sensors include the positioning of the sensors in order to cover much or all of a region, once or many times, and using sensors whose coverage abilities vary. Certain problem extensions arise in security applications and when sensors are deployed in hostile environments: it may not be possible to safely enter the area, in which case sensors may be distributed randomly from a distance; even if the positions can be chosen, there may be some minimal placement error which must be compensated for; it may not be possible to provide complete coverage, in which case we may settle for partial coverage or only barrier coverage and position sensors for improved intrusion detection. Another factor to consider when parties are acting in a coalition is that differing types of sensors may be deployed by the different parties, which must be taken into account when choosing positions. This short survey deals with some recent results that are especially applicable to such settings.

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INTRODUCTION

A major objective in the deployment of a network of sensors is effective coverage of a chosen region. This takes the form of monitoring for signs of danger, the presence of intruders, and other events. The coverage provided by a sensor network depends on the capabilities of the sensors, the environment in which they are deployed, their locations within that environment, and interactions between sensors and multiple parties sharing coverage of the region. This chapter presents results from select papers on the coverage provided by various deployment strategies, with emphasis on the kinds of situations that may apply to security and military contexts.

Sensor networks have many applications in military, environmental, and other contexts, which were not feasible before the advent of inexpensive, self-contained sensor nodes with enough capacity to store and relay data over wireless channels. For example, besides the obvious uses within military surveillance applications, sensor networks have been used in environmental studies to provide early alerts of forest fires and to monitor habitat, volcanic, and glacial activity.

There has been an explosion of research on the topic of ad hoc sensor networks in the last decade. For example, a popular article by Meguerdichian et al. (2001a) on best and worst case coverage had over 800 citations on Google Scholar as of August, 2009. A prominent survey paper published by Akylidiz et al. (2002) had more than 3,000 citations. Interest continues to mushroom. In 2009 alone, more than 30 conferences included sensor networks as a topic. Within the very large body of literature on ad hoc sensor networks, much effort has been expended examining placement issues. Since it is not feasible to create a comprehensive survey on the topic of sensor coverage, our goal is to provide broad outlines of some of the research that is especially of interest for ground-based coverage in security and military applications.

The sensors considered here are small, and perhaps capable of performing multiple tasks. As sensors, they are able to sense some aspect of the environment local to their physical location, and in addition are able to receive information and programming instructions, transmit information, execute a program, store a small amount of past data, and perform calculations. They can reconfigure their connectivity on the fly as needed (i.e., create and recreate an ad hoc network). They can be programmed to measure and report data upon request, periodically, or upon being triggered. In all cases, the information is forwarded to a base station for analysis.

This chapter focuses mostly examining those how sensors may be placed in large, continuous areas, with a special interest in coalition environments that arise in security and military environments. By a coalition environment, we mean one in which multiple partners are cooperatively interested in the coverage of an area. We assume, for the most part, that all the sensors of a coalition partner are of the same type with identical characteristics, e.g., the same fixed radius of coverage from their placement positions, although different partners in the coalition may have sensors with different characteristics. Two general categories of sensor deployment are random placement, e.g., by dropping the sensors from an airplane, as may be done in a hostile environment; and deliberate placement in specified locations, which can be accomplished when the region is small and accessible. A special case of deterministic placement is when sensors are placed on or approximately near grid points spaced equally apart in a regular pattern, such as a square or hexagonal lattice. We restrict ourselves here to coverage with statically placed sensors. That is, we do not consider the literature on mobile sensors (MANETs) and we only consider communications issues in passing. We leave other aspects of ad hoc sensor networks, including communications and network configuration, and the scheduling of sensor sleep cycles, to other chapters and other books. Two recent surveys...
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