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Bang Wang

Coverage Control in Sensor Networks

Springer

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To my wife Minghua, and our families

Preface

The advances in sensor design have decreased the size, weight, and cost of sensors by orders of magnitude, yet with the increase of higher spatial and temporal resolution and accuracy. With the fast progress of sensors design and communications technique, sensor networks have also been quickly evolving in both research and practical domains in the last decade. More and more sensor networks have been deployed in real-world to gather information for our daily life. Applications of sensor networks can be found in battlefield surveillance, environmental monitoring, biological detection, smart spaces, industrial diagnostics, etc. Although the technique of sensor networks has a very promising future, many challenges are still deserving lots of research efforts for its successful applications.

This book is devoted to coverage control, one of the most fundamental and important research issues in sensor networks. The aim of the book is to provide tutorial-like and up-to-date reference resources on various coverage control problems in sensor networks, a hot topic that has been intensively researched in recent years. Due to some unique characteristics of sensor networks such as energy constraint and ad-hoc topology, the coverage problems in sensor networks have many new scenarios and features that entitle them an important research issue in recent years. I have done my best to include in the book the most recent advances, techniques, protocols, results, and findings in this field. While I have tried to be as exhaustive as I could, the reader is advised to note that what is reported in this book is a picture of research approaches in this field taken at the middle of 2009.

Audience

This book is intended for graduate students, academic researchers, and industrial professionals who are interested in acquiring a big picture of various coverage control problems in sensor networks, including the problem scenarios, their assumptions and challenges, solution techniques and protocols. The book can serve as a reference book for undergraduate and graduate classes, or as a handbook for researchers, engineers, and developers working in the field of sensor networks.

Book Overview

This book is divided into four parts. The first part of this book provides general introductions, and the rest three parts are each devoted to a category of coverage control problems. In this book, we classify coverage problems into three categories, based on the coverage type, namely, *point coverage problems* (Part II), *area coverage problems* (Part III), and *barrier coverage problems* (Part IV).
Part I presents introductions on sensor networks and coverage control in sensor networks.

- Chapter 1 gives a short introduction to sensors, sensor nodes, and sensor networks, briefly describing the functions and characteristics of sensors, the architecture and components of sensor nodes, and the scenarios and applications of sensor networks. This chapter also discusses sensor network challenges and key research issues.
- Chapter 2 summarizes sensor coverage models mostly used in the literature, mainly elaborating their motivations, definitions, and applications. The sensor coverage model serves as a cornerstone of network-wide coverage control.
- Chapter 3 provides a big picture of various network coverage control problems, including the motivations, objectives, and design issues. We also discuss how the coverage control service can be integrated into the network protocol stack. At the end the chapter, we provide an informal definition and taxonomy for network-wide coverage control.

Part II is devoted to the point coverage problems. In the point coverage problem, the subject to be covered is a set of discrete points.

- Chapter 4 studies the node placement optimization problem for coverage configuration before network deployment, where the objective is to find the optimal locations to place sensor nodes to minimize network cost.
- Chapter 5 investigates the coverage lifetime maximization problem by controlling coverage characteristics in a randomly deployed network, where the objective is to optimally schedule sensors activities in order to extend network lifetime.

Part III is dedicated to the area coverage problems. In the area coverage problem, the subject to be covered is the whole sensor field.

- Chapter 6 discusses the *critical sensor density* (CSD) problem for coverage configuration before network deployment, where the objective is to find the least number of sensor nodes per unit area to provide complete coverage for the whole sensor field.
- Chapter 7 looks into the sensor activity scheduling problem of controlling network coverage characteristics in a randomly deployed network, where the objectives are to identify coverage redundant sensors and schedule sensors' activity in order to prolong the network lifetime.
- Chapter 8 introduces the node movement strategy problem for sensor networks containing mobile nodes, where the objective is to leverage mobile nodes to control network coverage. Mobile nodes change network coverage characteristics via

moving to the desired locations. The design of node movement strategy should balance between network coverage and movement cost.

Part IV discusses the barrier coverage problems. In the barrier coverage problem, the objective is to identify the desired coverage characteristics, if it exists, for a sensor network.

- Chapter 9 examines the coverage problems of building *intrusion barriers* for detecting intrusions of a mobile object when it traverses from one side to the other side of the sensor field. The trajectory of an intrusion mobile object is called its *traverse path*. The objective is to enable the covered points to form an intrusion barrier, stretching across the sensor field, and intersecting with every potential traverse path.
- Chapter 10 reviews the coverage problems of finding *penetration paths*. A penetration path is a continuous curve with arbitrary shape, spanning from one side to the other side of a sensor field. We assign a coverage measure (a real value) to represent the coverage characteristics of a single space point. The objective is to identify such a penetration path on which every single point satisfies the required coverage measure.

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Singapore *Bang Wang*
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Acronyms

2D	Two-dimensional
3D	Three-dimensional
ADC	Analogue-to-digital converter
ASIC	Application specific integrated circuit
BLUE	Best linear unbiased estimator
CDF	Cumulative density function
CPU	Central processor unit
CSD	Critical sensor density
DSC	Disjoint set cover
EEPROM	Electrically-erasable programmable read-only memory
FOV	Field of view
ILP	Integer linear programming
LLC	Logical link control
LP	Linear programming
MAC	Media access control
MEMS	Micro-electro-mechanical systems
OS	Operating system
OSI	Open system interconnection
RAM	Random access memory
RIS	Random independent sleeping
RMS	Root-mean-square
ROM	Read-only memory
RSIC	Reduced instruction set computer
TDMA	Time-division multiple access