# Preface

## Overview

Theoretical and algorithmic approaches to address key issues in Sensor networks, Ad hoc wireless networks, and Peer-to-peer networks (simply called SAP networks) have played a central role in the development of emerging network paradigms. These three networks are characterized by their ad hoc nature without infrastructure or centralized administration. Unlike infrastructured networks, such as cellular networks, where nodes interact through a centralized base station, nodes in a SAP network interact in a peer-to-peer fashion. As a result of the mobility (including join/leave the network) of their nodes, SAP networks are characterized by dynamically changing topologies. The applications of SAP networks range from civilian (file-sharing) to disaster recovery (search-and-rescue), and military (battlefield).

The main goal of this book is to fill the need for comprehensive reference material on the recent development on theoretical and algorithmic aspects of three related fields. Topics covered include: theoretical and algorithmic methods/tools: optimization, computational geometry, graph theory, and combinatorics; protocol security and privacy; scalability design; distributed and localized solutions; database and data management; operating systems and middleware support; power control systems and energy efficient design; applications; and performance and simulations.

This book brings together different research disciplines to initiate a comprehensive technical discussion on theoretical and algorithmic approaches to three related fields: sensor networks, ad hoc wireless networks, and peer-to-peer networks. The objective is to identify several common theoretical and algorithmic approaches that can address issues related to SAP networks. The central topic revolves around following the two questions: What are the central technical issues in SAP networks? What are the possible solutions/tools available to address these issues?

This book is expected to serve as a reference book for developers in the telecommunication industry or as a textbook for a graduate course in Computer Science and Engineering. It is organized in the following three groups as 48 chapters.

- Ad-Hoc Wireless Networks (19 chapters)
- Sensor Networks (16 chapters)
- Peer-to-Peer Networks (13 chapters)

Although many books have emerged recently in this area, none of them address all three fields in terms of common issues. This book has the following features and benefits:

- Coverage of three related fields: ad hoc wireless, sensor, and peer-to-peer networks. Allows the reader to easily cross-reference similar results in three fields.
- International groups of authors. Presents balanced coverage of research results done worldwide.
- Systematic treatment of theoretical and algorithmic aspects. Allows the reader easy access to some important results.

- Applications and uses of these networks. Offers good motivation for research in these fields.
- Authoritative materials on a broad range of topics. Provides a comprehensive treatment of various important topics by some of the leading researchers in the field.

## Common Theoretical and Algorithmic Issues

The following preliminary set of common theoretical and algorithmic issues is identified for SAP networks.

**Location Management** (in sensor networks, ad hoc wireless networks, and peer-to-peer networks): This issue addresses the problem of "where is X". This problem can be analyzed from two aspects: *update* and *page*. The updating process notifies the location servers of the current locations of nodes. In search of a node, the paging process queries the servers to identify the exact/possible locations of the mobile station before the actual search. This avoids the potentially high costs of doing a global search. Updating and paging costs are tradeoffs. More frequent updates can improve the accuracy of the information in location servers, thus reducing the paging costs. On the contrary, less frequent updates can save updating costs, but may incur higher paging costs, especially for highly mobile stations. Many analytical tools such as queueing analysis and Markov chain analysis were used in this area. Graph theoretical models are used in peer-to-peer networks based on building an overlay network.

**Security and Privacy** (in sensor networks, ad hoc wireless networks, and peer-to-peer networks): Security is the possibility of a system withstanding an attack. There are two types of security mechanisms: preventive and detective. The majority of the preventive mechanisms have cryptography as building components. The goal of system security is to have controlled access to resources. The key requirements for SAP networks are confidentiality, authentication, integrity, non-repudiation and availability. SAP networks are more prone to attack because of their dynamic and/or infrastructure nature. The attacks on networks can be categorized into interruption, interception, modification, and fabrication. In addition to various "attacks", a number of "trust" issues also occur in SAP networks. The cryptographic algorithms are widely used in this area.

**Topology Design and Control** (in sensor networks, ad hoc wireless networks, and peer-to-peer networks): Topology design deals with the way to control the network topology to achieve several desirable properties in SAP networks, including small diameter and small average node distance in peer-to-peer networks, and a certain level of node connectivity in sensor and ad hoc wireless networks. In general, each node has similar number of neighbors, and the average nodal degree should be small. Regular and uniform structures are usually preferred. In many cases, the topology control is tied to energy-efficient design. The traditional graph theory is usually used to deal with topology control.

**Scalable Design** (in sensor networks, ad hoc wireless networks, and peer-to-peer networks): Scalable design deals with how to increase the number of nodes without degrading system/protocol performance. The most common approach for supporting scalability is the clustering approach used both in sensor networks and ad hoc wireless networks. Basically, the network is partitioned into a set of clusterheads, with one clusterhead in each cluster. Clusterheads do not have connection, but each clusterhead directly connects to all its member. In sensor networks, the clustering approach is used to reduce the number of forward nodes (that contact the base station directly) and, hence, to reduce overall energy consumption. The traditional scalability analysis is normally used.

**Energy-aware Design** (in sensor networks and ad hoc wireless networks): Energy-aware design has been applied to various levels of protocol stacks. Most of works have been done at the network layer. Several different protocols have been proposed to manage energy consumption by adjusting transmission ranges. In the source-independent approach, all nodes can be a source and are able to reach all other nodes by assigning appropriate ranges. The problem of minimizing the total transmission power consumption (based on an assigned model) is NP-complete for both 2-D and 3-D space. Various heuristic solutions exits for this problem. At the MAC layer, power saving techniques for ad hoc and sensor networks can be divided into two categories: *sleeping* and *power controlling*. The sleeping methods put wireless nodes into periodical sleep state in order to reduce the power consumption in the *idle listening* mode. Both graph theory and optimization methods are widely used in this area.

**Routing and Broadcasting** (in sensor networks and ad hoc wireless networks): This issue deals with trade-offs between proactive and reactive routing, flat and hierarchical routing, location-assist and non-location-assist routing, source-dependent and source-independent broadcasting. These trade-offs focus on cost and efficiency and are dependent on various parameters, such as network topology, host mobility, and network and traffic density. Various graph theoretical models (such as dominating set) and computational geometrical models (such as Yao graph, RNG (relative neighborhood graph), and Gabriel graph) have been used. Graph theory, distributed algorithms, and computational geometry are widely used in this area.

# Acknowledgment

I wish to thank all the authors for their contributions to the quality of the book. The support from NSF for an international workshop, held at Fort Lauderdale, Florida in early 2004, is greatly appreciated. Many chapters come from the extension of presentations at that workshop.

Special thanks to Rich O'Hanley, the managing editor, for his guidance and support throughout the process. It has been a pleasure to work with Claire Miller, who collected and edited all chapters. I am grateful to them for their continuous support and professionalism.

Finally, I thank my children, NiNi and YaoYao, and my wife Ruiguang Zhang for making this all worthwhile and for their patience during my numerous hours working both at home and at the office.

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