

Preface

Sensors represent a basic building block of technology systems we depend much on in our daily activities such as mobile phones, smart watches, smart cars, home appliances, etc. To date Wireless Sensor Networks (WSNs) represent perhaps the most widely deployed and highly explored networks that use sensors as part of their systems. It is through such a network that sensors communicate, share and fuse information, and thus provide foundations for applications such as large scale monitoring, surveillance, home automation, etc. With the advent of Internet of Things (IoT) and wearable devices embedded with sensors, new and exciting applications of WSNs have emerged. We expect a greater convergence of WSNs with these exciting new and emerging technologies such as the IoT.

Through this book, we not only present a structural treatment of the building blocks of WSNs, which include hardware and protocols architectures, but we also present systems-level view of how WSNs operate including security, coverage and connectivity, and localization and tracking. One can use these blocks to understand and build complex applications or pursue research in yet open research problems. The areas are wide: how one may deploy the wireless sensor nodes? How sensor nodes within the wireless network communicate with each other? What is their architecture? What are the security issues? And many more questions and their answers are provided for general engineering and science audience.

The purpose of writing this book is to give a systematic treatment of foundational principles of WSNs. We believe that this treatment provides tools to build or program specialized applications and conduct research in advanced topics of WSNs. Since each of us has academic experiences, we present the material from a pedagogical view with each chapter providing a list of references and a list of short questions and exercises. The field is growing at such rapid pace that it is impossible to cover all new developments; therefore, each chapter provides information with a balance towards pedagogy, research advances, and an enough introduction of important concepts, such that an interested reader should be interested to explore further can then refer to cited papers in the references.

Our discussions in the book are motivated by demands of applications, thus most of the material, especially in the later chapters, has applications in areas where sensor networks may be used or deployed.

Any student with a university undergraduate education in mathematics, physics, computer science, or engineering will feel comfortable following the material. Readers primarily interested in qualitative concepts rather than the underlying mathematics or the programming of WSNs can skip the more mathematical parts without missing the core concepts.

The book can serve a basis for one-semester to two-semester course in WSNs. One can focus on WSN foundations or WSN security or coverage and control. We suggest the following:

- One-semester course with a focus on *coverage and control* of WSNs: Chaps. 1–3, 5, 6, and 8.
- One-semester course with a focus on *security* of WSNs: Chaps. 1, 2, 4, 7, and 8.
- One-semester course with a focus on *foundations* of WSNs: Chaps. 1–3, 5, and 7.
- One-semester course with a focus on WSN *hardware*: Chaps. 1–3, 5, and 8.

For a two-semester sequence, one can pick and choose the chapters. For example, one scenario may be as follows: follow first three chapters in the first semester supplemented by parts of chapters on security, coverage or control. A more applied course may include Chap. 8 in the first semester replacing fully or partially the content from security, coverage, and control. In the second semester, Chaps. 4–6 can be covered supplemented by course projects.

The book is organized as follows.

Chapter 1 provides foundations and gives a general description of WSNs, most common application where WSNs are used and common communication protocols that are basis for a WSN.

Chapter 2 covers background material needed to understand WSN topology, protocols, routing, coverage, etc. We include basic mathematical models that are used later in the book such as Voronoi diagrams and Delaunay triangulations. This chapter is recommended to be studied before coverage and connectivity or localization and tracking are covered.

Chapter 3 presents a WSN architecture including both hardware structure and functional details of all major components in the sensor node and a layered network architecture and description of various protocols. When we discuss hardware components, we present each building block of a sensor node and their important functional principles. For instance, we list important and common sensors that engineers and scientist might encounter when dealing with WSNs, and discuss their sensing principles. Similarly, when we discuss medium access protocols, we talk about common protocols that are currently in use.

Chapters 1–3 cover a basic background related to WSNs. Chapter 4 is a more focused material related to WSN security issues. Why are WSN predisposed to various security threats and what are the most important vulnerabilities? We cover basic attack and defense strategies that are applicable to a WSN. When discussing

security, robustness of the network is closely related to sensor faults, proper sensor fault detection and mitigation. Malicious data on one sensor node can be interpreted and detected as a fault within the next hop in multi-hop network.

Chapter 5 presents coverage and connectivity, two related characteristics of the network and important quality of service measures. We discuss basic mathematical models for coverage and connectivity and then study more in-depth theoretical concepts related to coverage holes. This is also important from the security point of view where any coverage hole in the sensor network might represent a vulnerability point.

Chapter 6 covers another advanced topics—localization and tracking as well as important algorithms that are used today in such applications.

Chapter 7 provides a quality of service overview. Here we acknowledge that some quality of service measures are already covered in other chapters, such as coverage, and we discuss in more details only such measures that have not been covered previously.

Chapter 8 presents WSN platforms that are in use, some that have more of a historic value at the moment, and some that witnessed their own evolution into other closely related products.

We have tried to find a balance between simplicity, depth of treatment, and covering enough material without the risk of appearing superficial. We hope that we have succeeded in this endeavor.

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