

# Preface

With the advent of the global positioning system (GPS) in the 1990s, civilian applications for location-based services have been increasing steadily. As the cost of GPS chipsets has decreased, integration into mobile/cellular phones has become feasible, further driving the rapid development in the consumer market. The GPS was originally developed for military applications with global reach, but with the increasing urbanization of the world population the main location-based services growth area is likely to be in cities. Further, as city dwellers spend most of their time indoors, where GPS is not effective, it appears that future developments of positioning systems are likely to require good performance within buildings. Thus, the focus of this book is on short- to medium-range positioning systems, with a particular emphasis on indoor performance with a projected accuracy of 1–2 m. Such systems, particularly those using cheap hardware, are not currently available, but developments in the large-scale integration of both analog radios and digital signal processing chips suggests that the projected performance requirements will soon be met. The applications of such systems include people tracking within buildings, inventory management, security applications and positioning in wireless sensor networks.

The nature of indoor positioning systems is somewhat different from outdoor systems such as GPS. In the literature on GPS, much of the emphasis is on the performance of the receiver, as the satellite infrastructure is the responsibility of the US Department of Defense. In contrast, an indoor positioning system must involve all aspects, including timing and frequency synchronization, the effects of internal delays in the hardware and communications between nodes of the network. All these aspects are particularly challenging, as to achieve the 1–2 m accuracy typically requires very precise timing measurements to the order of a nanosecond. Because of the nature of indoor applications, another difference in the systems' architectures is the probable adoption of ad hoc networking, rather than using the traditional "fixed" base stations and mobile nodes typical of long-range positioning systems. While position determination based on traditional hyperbolic navigation principles is likely to remain important, we may see a widespread employment of other position determination techniques, including signal-strength methods, use of angle-of-arrival data, hybrid radio-ultrasonics techniques and even position determination simply based on the detection of neighboring nodes in a network. Because of the diversity of location-based services and applications, this book covers a wide range of positioning techniques and processing algorithms currently dispersed in the technical literature, rather than focusing on particular positioning systems. The systematic treatment of these techniques and algorithms in the book should prove beneficial to system designers, researchers and graduate students.

This book is broadly organized into two parts. The first part is on the background aspects affecting positioning performance, such as indoor radio propagation and signal processing. The second part is on the details of various position-determination algorithms and their associated positional accuracy performance.

Chapter 1 provides an introduction to indoor positioning and provides a summary of various possible technologies and the desirable characteristics of future systems. Chapters 2–5 provide an introduction to aspects which have an important influence on the performance of indoor positioning systems. Chapter 2 provides an overview of the characteristics of indoor radio propagation, particularly related to the important topics of excess propagation losses and delays. Using this material, designers can estimate the likely range and accuracy of a system. Chapter 3 is an overview of signal processing, in particular as it relates to spread-spectrum signals. The concentration on spread-spectrum modulation is attributed to the desire for accurate position determination, which in turn necessitates wide spectral bandwidths. The largest available bandwidths with reasonably high transmitter power necessary for adequate indoor range are limited to the industrial, scientific and medical bands, which restrict transmissions to spread-spectrum signal. Chapter 4 provides analysis of time-of-arrival detection accuracy in the presence of Gaussian noise and multipath signals. Chapter 5 provides an overview of indoor tracking systems and introduces important topics described in more detail in subsequent chapters.

The second part of the book, Chapters 6 to 14, focuses on the details of position-determination algorithms. Chapters 6 and 7 provide details of position determination based on the traditional base station architecture and the measurement of range or time-of-arrival data. Chapters 8 and 9 provide statistical analysis of the accuracy of position determination for the methods described in Chapters 6 and 7. Chapter 10 describes multipath mitigation techniques, which are particularly important in the indoor environment. Chapters 11–13 focus on methods applicable to ad hoc networks and low-accuracy position determination, as in wireless sensor networks. Finally, Chapter 14 provides a wide range of techniques for determining whether the received signal is line-of-sight or non-line-of-sight path; the determination of the path type can be useful in improving position accuracy.