Mechanisms and Games for Dynamic Spectrum Allocation

Presenting state-of-the-art research into methods of wireless spectrum allocation based on game theory and mechanism design, this innovative and comprehensive book provides a strong foundation for the design of future wireless mechanisms and spectrum markets.

Prominent researchers showcase a diverse range of novel insights and approaches to the increasing demand for limited spectrum resources, with a consistent emphasis on theoretical methods, analytical results, and practical examples. Covering fundamental underlying principles, licensed spectrum sharing, opportunistic spectrum sharing, and wider technical and economic considerations, this singular book will be of interest to academic and industrial researchers, wireless industry practitioners, and regulators interested in the foundations of cutting-edge spectrum management

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"In the 21st century, the radio-frequency spectrum is a highly valuable resource. Its allocation is an economic problem, requiring a deep understanding of wireless communications engineering. This book, with contributions from many of the most prominent experts, is a must-have for anyone interested in this new, exciting, inter-disciplinary field."

Stephen Hanly
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Preface

Mobile communications is a cornerstone of the ongoing global communication revolution and an indispensable part of the information age. Mobile phones, originally intended mainly for voice services, have spread throughout the world at an unprecedented rate. Nowadays, mobile devices such as smart phones and tablets seamlessly combine previously desktop-level computing power with mobile communications, and are enjoying similar growth rates. That has been coupled with worldwide and aggressively growing public demand for mobile communication and associated services such as broadband internet access.

Mobile communications relies on both networking infrastructure and the carefully managed use of the electromagnetic (wireless) spectrum. It is well known that the spectrum useful for wireless communications is a limited physical resource, and celebrated results from information theory imply that this in turn limits the types of services that this spectrum can support. Given the increasing demand for mobile broadband data services, it is clear that wireless spectrum is a resource that needs to be allocated and managed efficiently.

Until recently, the allocation of spectrum to different applications has been static, and often inefficient. Today, realizing the value of this scarce resource, government agencies and industry are looking for innovative ways of sharing wireless spectrum in a dynamic, efficient, and user-centric manner. Recent wireless networking technologies such as cognitive radios, femtocells, spectrum sensing, orthogonal frequency-division multiplexing (OFDM) and multiple-input and multiple-output (MIMO) methods along with dynamic spectrum sharing schemes such as white-space spectrum usage and secondary spectrum markets, are creating the impetus for the evolution towards dynamic and efficient spectrum allocation.

Advances in wireless networking technologies have occurred at a rapid pace, providing new opportunties for engineers, government agencies, commercial enterprises, and policy-makers to exploit interactions and set future directions. At this point, there is a need for a deeper understanding of the spectrum allocation problem, which has both technological and economic dimensions. Approaching the subject purely from a technological point of view will only yield a partial understanding. Likewise, pure policy-based or economic perspectives will be necessarily limited since the value of wireless spectrum depends on available technologies that can exploit it. Therefore, further research is needed to build a sound basis of understanding encompassing all of these aspects.

A better understanding of the basic technological, economic, and application-level issues in wireless spectrum allocation will, on the one hand, potentially lead to better

technologies for increasing spectrum usage efficiency. On the other hand, novel regulatory frameworks, including the introduction of new market mechanisms for spectrum sharing, may emerge. Finally, the widespread availability of mobile computing has already had a major societal impact, affecting productivity, social interactions, and organization. Enhanced performance and availability combined with new mobile applications due to more efficient use of wireless spectrum will continue to amplify this impact.

This book aims to provide scientific insights into wireless spectrum allocation based on the framework provided by game theory and mechanism design. Presenting contributions from numerous prominent researchers in this area, the book gives an overview of current research results, and helps to build the foundation needed for designing future mechanisms for allocating and sharing spectrum.

Wireless networks are evolving to become virtual platforms on which multiple independent decision makers (agents) can interact and share resources dynamically over multiple time scales. These decision makers often have conflicting preferences and may act selfishly when obtaining network resources. Similar types of interactions can also exists in dynamic spectrum markets and opportunistic spectrum sharing schemes. Game theory is used to study multi-person decision making and provides an analytical framework for modeling and understanding player interactions in various resource sharing scenarios. Mechanism design focuses on how to design rules for interacting agents such that those interactions lead to desirable outcomes when each participant follows a strategy aligned with her own objectives. Both of these theoretical tools are useful for the analysis and design of spectrum sharing schemes, and constitute the basis for this book along with other fundamental tools from information theory, optimization, signal processing, and control theory.

The book is organized in three parts: (a) theoretical fundamentals; (b) cognitive radio and sharing of unlicensed spectrum; and (c) management and allocation of licensed spectrum. The first part focuses on fundamental methods relevant to spectrum allocation in general. These range from physical layer analysis in wireless networks to game-theoretic models and mechanisms for spectrum markets. The second part of the book focuses on opportunistic spectrum sharing in unlicensed bands such as evolution of WiFi-like schemes, cognitive radio, and white-space spectrum usage. The third part discusses licensed spectrum sharing approaches including dynamic and secondary spectrum markets.

This book is appropriate for researchers and graduate students in engineering, computer science, and economics. While the emphasis is on theoretical models and the presentation of analytical results, we believe that it should also be beneficial for regulators and practitioners in industry who are interested in the technical foundations of spectrum management. The various contributions from prominent researchers collected in this book offer diverse perspectives on the underlying technical issues pertaining to both licensed and unlicensed bands. The book can be adopted as a reference for graduate-level wireless networking and communication courses that cover spectrum allocation issues, and for courses in computer science and economics that cover mechanism design, where spectrum allocation serves as a potential application.