Preface

Presently, we rely on the wireless devices and systems to not only enable on-demand, pervasive communications for a large proportion of the population, but also other critical application areas such as scientific and medical research, industrial control and automation, and public safety. As the wireless communication systems and its applications continue to flourish, the demand for precious spectrum resources will continue to grow. In the foreseeable future, we expect that the demand for spectrum will continue to increases as new wireless technologies and applications with high data throughput requirements continue to emerge. This voracious enthusiasm for additional spectrum resources cannot be met by simply allocating new spectrum. The usable capacity of spectrum must be expanded with innovative technologies, regulatory reforms, and removal of market barriers. The cognitive radio is one of the innovative technologies that have the potential to effectively address the spectrum shortage problem and radically change the way we utilize spectrum. Due to its potential impact, various stakeholders—including regulatory policymakers, wireless device manufacturers, telecommunication operators, and academic researchers—have shown strong interest in it, especially with respect to research and development.

Therefore, the cognitive radio has emerged as a prone candidate for exploiting the increasingly flexible licensing of the wireless communication system. The regulatory bodies have come to realize that most of the time, a large portion of certain licensed frequency band remain empty/unused. To remedy this, new regulations would allow for devices which are able to sense and adapt to their spectral environment, such as cognitive radio to become secondary user and such users are wireless devices that opportunistically employ the spectrum already licensed to the primary users. The primary users generally associated with the primary spectral licensed holder and thus have higher priority right to the spectrum. The intuitive objective behind secondary spectrum licensing is to improve the spectral efficiency of the network, whereas depending on the type of licensing and not affecting higher priority users.

In the cognitive radio network, the medium access control (MAC) protocols play an important role to exploit the spectrum opportunities, manage the interference to the primary users and coordinate. The dynamic leasing, in which some wireless devices opportunistically employ the spectrum rather than choose for a long-term sub-lease. In order to exploit the spectrum, we require a device which is able to sense the communication opportunity and then take actions based on the sensed environment. The cognitive radio offers a novel way of solving spectrum under-utilization problems. The emergence of FCC's secondary market initiative, it has been brought on by both the obvious desire for spectral efficiency, as well as empirical measurements showing that most of the time certain licensed frequency remain unused. The goal of secondary market initiative is to remove unnecessary regulatory barriers to new secondary market oriented policies such as

(1) Spectrum leasing, which allow non-licensed users to lease any part, or the entire spectrum from the licensed user.
(2) Dynamic spectrum leasing, which is a temporary and opportunistic usage of spectrum rather than a large term sub-lease.
(3) Private commons, which a licensee could allow non-licensed user access to his/her spectrum without a contract, optional with access fee.
(4) Interruptible spectrum leasing, which would be suitable for a lesser that wants a high level of assurance that any temporally in use, or leased, to an incumbent cognitive radio could be efficiently reclaimed if needed. A prime example would be the leasing of the generally unoccupied spectrum allocated to the government or local enforcement agencies, which in time of emergency could be quickly reclaimed.

This book puts together a rich set of research articles featuring recent advances in theory, design, and analysis of cognitive radio wireless communication networks. The book consists of 10 chapters, which cover a wide range of topics related to the cognitive radio technology, in particular, the topics covered in this book include fundamental challenges and issues in designing cognitive radio systems, information-theoretic analysis of cognitive radio systems, spectrum sensing and co-existence issues, adaptive physical layer protocols and link adaptation techniques for cognitive radio, different techniques for spectrum access by distributed cognitive radio, cognitive medium access control (C-MAC) protocols. The book is organized as follows. Chapter 1 provides a comprehensive survey with state of the art of the various spectrum sharing techniques and the fundamental issues related to cognitive radio design and the major research challenges mostly from a signal processing and communication-theoretic perspective. The potential advantages, limiting factors, and characteristic features of the existing cognitive radio spectrum sharing domains are thoroughly discussed. As the complexities of wireless technologies increase, novel multidisciplinary approaches for the spectrum sharing/management are required with inputs from the technology, economics and regulations. To identify the available spectrum resource, decision on the optimal sensing and transmission time with proper coordination among the users for spectrum access are the important characteristics of spectrum sharing methods.

The spectrum sensing is the key requirement and one of the most challenging issues of the cognitive radio system. In this context, Chap. 2 presents a survey of the physical layer spectrum sensing techniques for cognitive radios. The major challenges in spectrum sensing are outlined and several techniques for improving spectrum sensing performance are discussed. Further, a hybrid model for non-cooperative spectrum sensing has been presented, with this terminology the proper channelization of the three techniques has been performed with relevant discussion. The presented approach helps in detecting the idle spectrum opportunistically with better utilization of the spectrum under non-cooperative sensing with enhanced spectrum efficiency. We have also explored the sensing under cooperative environment. The presented approach helps in detecting the idle spectrum bands (spectrum holes that is the underutilized sub-bands of the radio spectrum) opportunistically with better utilization of the spectrum under non cooperative sensing with increase in the overall spectrum efficiency.

In Chap. 3, we have proposed a novel multichannel cooperative MAC protocol for the distributed cognitive radio network which has the back-off algorithm for contention solving among the competing cognitive users. The back-off algorithm for resolving collision among the competing users has allowed the collided cognitive users to become successful by selecting another contention slot from the increased contention window. The increased number of successful users has enhanced the throughput of the cognitive radio network by transmitting their data over the detected idle licensed channels. Moreover, the optimum number of contention slots have been achieved which has maximized the number of successful cognitive users as well as throughput.

In Chap. 4, the cognitive radio MAC protocol in practical scenario is considered and the perfect and imperfect sensing effect on the performance of throughput and energy efficiency of the cognitive radio network is presented. The imperfect sensing resulted due to false alarm has affected the system performance of cognitive radio network by missing the opportunities of spectrum use in comparison to the perfect sensing, as demonstrated in the simulation results. In addition to this, the optimum number of contention slots has been obtained for the proposed MAC protocol which has avoided contention slots throughput tradeoff problem. Moreover, the performance of MAC protocol for different licensed channels utilization probability has been simulated. The simulation results have illustrated that throughput and energy efficiency of the MAC protocol for imperfectly sensed environment is less as compared to that of the perfect sensing scenario and the interference to the primary user is less in the proposed protocol for lower values of miss detection probability.

In Chap. 5, the scheme for maximizing the bandwidth efficiency by util.ng the wasted bandwidth of the licensed channels in the distributed cognitive radio MAC protocol has been proposed. In addition to this, the contention resolving algorithm has been also applied in this proposed bandwidth maximization scheme as discussed in Chap. 3. Further, the bandwidth wastage in the cooperative distributed MAC protocol has been minimized by transmitting data of the cognitive users over the idle licensed channels, which are unutilized in the sensing-sharing and contention interval. The proposed technique has significantly enhanced the throughput of the cooperative distributed network. Moreover, the comparison of the proposed scheme in this chapter has been performed with the SMC-MAC protocol.

Chapter 6 concerns the energy efficiency of cognitive radio terminal and have obtained the optimum transmit power for the cognitive terminal at which the energy efficiency is maximum. It is further shown that the complexity of proposed algorithm for computing the optimum transmit power is very less. We have considered different scenario of channel conditions at different channel gain and have maximized the energy efficiency of the cognitive radio terminal.

In Chap. 7, a technique to eliminate the sensing-throughput trade-off of the conventional approach by increasing throughput of cognitive radio user and simultaneously reducing interference with the primary users has been explored. This presented technique is also reducing the data loss rate by decreasing collision of frames of primary and secondary users. Finally, the simulation results have been provided which is compared with conventional and proposed approach. From these simulation results, it is demonstrated that the throughput is more for proposed approach as compared to that of the conventional approach.

In Chap. 8, we have explored an optimal power allocation scheme for the spectrum sharing with imperfect channel state information between the cogni-tive/secondary user (CU) and licensed/primary user (PU) over Rayleigh fading environment. We have analyzed the ergodic capacity of CU link under the combi-nation of peak transmit power and peak/average interference power constraints with or without primary user interference. In addition to this, the outage capacity with multiple primary user interference is also analyzed with the error variance under the joint peak transmit power and peak interference power constraint as well as individual peak interference power constraint. Moreover, the power expenditure is also investigated to achieve the lower limit of ergodic and outage capacity. The minimum mean square channel estimation technique is used for the channel estimation between CU and PU. However, the convex optimization method is used for the optimal power allocation.

In Chap. 9, we have considered two adaptation policies for spectrum sharing in cognitive radio such as power adaption policy and rate and power adaptation for multilevel quadrature amplitude modulation (M-QAM) format. We have obtained the channel capacity for both these policies under Rayleigh and Rician fading environment. The rate and power of secondary transmitter is varied based upon the channel state information (CSI) of the secondary link and sensing information, which shows the activity of the primary user. We also considered the channel fading in between the secondary user and primary user and obtained the secondary transmitter power adaption policy for Rayleigh and Rician fading environment under peak transmit power and interference power constraint.

Chapter 10 presents a cross-layer optimized design framework for cognitive radios in a dynamic spectrum access environment. In general speaking, layered architectures like Open Systems Interconnection (OSI) and Transmission Control Protocol (TCP) models forbids direct communication between the non-adjacent layers and communication between the adjacent layers is also limited in such a way that higher layer protocol only makes use of the services at the lower layers and is not concerned about the details of how the service is being provided. This in turn becomes bottleneck for new emerging wireless services. Therefore, cross-layer optimization work related to wireless and cognitive radio network has been reviewed in this chapter. In addition, MAC layer parameters optimization with the help of cross-layer interaction has been emphasized and various challenges in this interaction have been presented.

In summary, the book provides a unified view of the state of the art of cognitive wireless communications and networking technology, which should be accessible to a readership with basic knowledge about wireless communications and telecommunications networking. The readership may find the rich set of references in each of the chapters very useful. The authors have performed a good job by providing a concise summary of all the chapters at the preface of the book. I would strongly recommend the book to graduate students and researchers and engineers working or intending to work in the area of cognitive radio.

Although numerous journal/conference publications, tutorials, and books on cognitive radio have been published in the last few years, the vast majority of them focus on the various physical-layer attributes of the technology. More importantly, these technical publications discuss the cognitive radio in isolation, essentially as a standalone system or network, with little regard for how it may interact with legacy wireless systems or how heterogeneous cognitive radio systems may collaborate with each other. Although this book's main theme is cognitive radio, its specific focus areas are quite different from the existing literature. The prime intent of this book is to provide a comprehensive discussion on how cognitive radio technologies can be employed to enable efficient wireless communication system. In other words, the discussions in this book revolve around how cognitive radio technologies can be used to enable various wireless networks to coexist and efficiently share spectrum. The intended readership of this book includes wireless communications industry researchers and practitioners as well as researchers in academia. The readership is assumed to have background knowledge in wireless communications and networking, although they may have no in-depth knowledge of cognitive radio technologies. The intention of this book is to introduce communication generalists to the technical challenges of the various coexistence techniques and mechanisms as well as solution approaches which are enabled by cognitive radios.

This book distinguishes itself from the existing prosperous literature of cognitive radio networks. The existing literature presents a self-contained introduction of the emerging cognitive radio networking paradigm outlining the theoretical fundamentals and requirements for enabling such a technology. The emphasis of such books is on the theoretical design, optimization, and performance evaluation of opportunistic spectrum access in cognitive radio networks.

The main challenge of existing distributed opportunistic spectrum management schemes is that they do not consider the unavoidable practical limitations of today's cognitive radio networks such as the inability to measure the interference at the primary receivers. Consequently, optimizing the constrained cognitive radio network performance based only on the local interference measurements at the cognitive radio senders does not lead to truly optimal performance due to the existence of hidden or exposed primary senders. More specifically, the existing schemes have a cognitive radio sender decide its transmission strategy based on its local interference measurement—while such decisions should have been made based on the interference measurement at the nearby primary receivers to be interfered with its transmission. However, there does not exist a practical mechanism that enables a cognitive radio to determine the interference at nearby primary receivers. Furthermore, the existing transceiver technologies and spectrum measurement techniques are incapable of accurately assessing the spectrum usage over a wide frequency range due to the limitations imposed by the transceiver hardware.

This book is an extension of the Ph.D. dissertation of Dr. Shweta Pandit submitted to the Jaypee University of Information Technology Waknaghat, Solan under the supervision of Dr. Ghanshyam Singh. This book targets a wide range of readers including but not limited to researchers, industry experts, and senior undergraduate as well as graduate students. On the one hand, the readers with theoretical interests will experience an unprecedented treatment of the conventional cognitive radio network performance optimization problem that takes into account the practical limitations of recent technologies. Further, the readers interested in real-life distributed cognitive radio network realization will be exposed to a first-of-its-kind clean-slate implementation approach that demonstrates the significant multi-faced performance improvement. This book offers the reader a range of interesting topics portraying the current state of the art in cognitive radio technologies. In simple terms, while several existing opportunis-tic spectrum access approaches have been developed and theoretically optimized, they are challenged by the inherent constraints of practical implementation technologies. Analyzing these constraints and proposing an attractive and practical solution to counter these limitations are the basic aims of this book.

The authors are indebted to a numerous colleagues for the valuable suggestions during the entire period of manuscript preparation and especially thankful to the Professor B.N. Basu, and Professor S.K. Kak, IIT (BHU), India, for the motivation. We would like to acknowledge and thank a number of colleagues as well as M. Tech. and Ph.D. students who have made this book possible. In particular, we would like to acknowledge Ms. Shipra Kapoor and Ms. Bindu Bharti who have provided invaluable inputs that helped shape the contents of this book. The authors would also like to thank publishers at Springer, in particular Brian P. Halm, Charles B. Glaser, and Nicole Lowary for their helpful guidance and encouragement during the creation of this book. The authors would not justify their work without showing the gratitude to their family members who have always been the source of strength to tirelessly work and to accomplish the assignment.

Special Acknowledgements

We sincerely thank the authorities of Jaypee University of Information Technology, Wakanaghat, India for their kind support to come up with this book.

Solan, India

Shweta Pandit
Ghanshyam Singh

http://www.springer.com/978-3-319-53146-5

Spectrum Sharing in Cognitive Radio Networks
Medium Access Control Protocol Based Approach
Pandit, S.; Singh, G.
2017, XXIII, 254 p. 81 illus., 58 illus. in color., Hardcover
ISBN: 978-3-319-53146-5