Preface

The tremendous increase in portable devices and computers has led to an ever-growing demand for greater data rates for wireless transmission, and thus to an increasing demand for spectrum channels. Conventionally, a licensed spectrum is assigned for comparatively long time spans and projected to be used solely by the license holder (primary user). This static assignment can create both a bottleneck and an under-utilized spectrum. Such inefficient utilization of inadequate wireless spectrum resources has motivated researchers and practitioners to look for advanced and innovative technologies that will enable more efficient use of spectrum resources in both a smarter and a more efficient manner.

INTRODUCTION

To manage the radio spectrum more efficiently, we must realize that since such utilization is dynamic, its management should also be dynamic. In 2003, the Federal Communications Commission (FCC) proposed the development of Dynamic Spectrum Access (DSA), also known as Opportunistic Spectrum Access (OSA). Since then, important efforts have been undertaken to turn this concept into reality. One of these efforts is Cognitive Radio (CR), which has appeared as a supporting platform for DSA. CR combines Artificial Intelligence (AI) with Software-Defined Radio (SDR) technology.

Cognitive Radio is an emerging technology, the primary objective of which is the most efficient utilization of the radio spectrum. A cognitive radio, built on a Software-Defined Radio (SDR), is defined as an intelligent wireless communication system that is aware of the environment, learns from it, and adapts to statistical variations in input stimuli to achieve two main purposes: highly reliable communication and efficient use of radio spectrum.

To accomplish its mission, a cognitive radio executes a series of processes known as a cognitive cycle. This cycle includes three stages: Observing, Decision Making, and Taking Action. Different processes take place at each stage of this cycle. These processes involve techniques drawn from different fields, including digital signal processing, estimation theory, and artificial intelligence. A summary of the main aspects of each of these is given next.
DYNAMIC SPECTRUM MANAGEMENT USING SOFTWARE-DEFINED AND COGNITIVE RADIO TECHNOLOGIES

A cognitive radio is aware of the context wherein it operates. This awareness includes knowledge of the environment, the communication requirements of the users, the regulatory policies, and its own capabilities. Spectrum sensing and channel estimation support the context awareness of a cognitive radio. Spectrum sensing is the process of obtaining awareness about the spectrum usage and the existence of primary users, incumbent users in a determined area, so secondary cognitive users can utilize empty channels, which in turn make the use of the radio spectrum more efficient. Channel estimation is the process of collecting Channel-State Information (CSI) to assess the channel capacity and its characteristics.

Sensing is critical in order to detect when a channel is being used by other users. In terms of spectrum management, sensing allows for the identification of spectrum holes to access the spectrum dynamically and provide dynamic spectrum management. In addition, reliable sensing can prevent interference. SNR and RSS (Received Strength Signal) are basic ways of sensing that help estimate how far apart the nodes are and determine if they are about to lose a connection. Knowing that information allows the cognitive radios to switch to a different frequency channel and either modify the modulation scheme or increase transmission power.

In cognitive radio systems, channel estimation is necessary for the most optimal adjustment of system parameters to changing conditions. In mobile communication systems, such as vehicle networks, the received signal strength oscillates, as the vehicle travels through interference patterns caused by multipath, shadowing due to obstacles, and change in distance between nodes. Generally, CR systems are designed to maximize their throughput and reliability for a given Quality of Service (QoS). This can be accomplished by adapting the system parameters to the fluctuations created by multipaths and shadowing. This process, however, requires estimation, prediction, and tracking of the received signal as accurately as possible. Two of the most popular estimation approaches are Bayesian estimation and maximum likelihood estimation.

The capability of making decisions is what distinguishes a cognitive radio from a conventional radio. It enables the cognitive radio to adapt itself to fulfill the specific requirements of a determinate application. For instance, if the radio starts experiencing problems from interference, the logical move is to switch to another channel. The CR needs a strategy, however, to decide when to switch the channel, determine the best channel to switch to, etc., always keeping in mind the goal. This goal could be maximizing throughput, reliability, or minimizing power consumption and/or delay. It also can be a combination of these features or others. All these features need to be quantifiable in order to formulate a mathematical procedure that can be precisely executed by a computer or computation device.

Making decisions is associated with other processes: orienting, planning, and learning. Orienting establishes priorities based on the observations. If the priority is normal, the next stage is planning, which implies generating and/or evaluating the alternatives. If the priority is high, then the next stage is making a decision on the resources to be allocated. Learning receives information from the other processes to build knowledge, and this knowledge feeds back to the system to refine the deciding process.

The Cognitive Engine (CE) is the entity in the CR that executes orienting, planning, deciding, and learning tasks. The CE takes the stimuli, analyzes them, and classifies the situation. The CE also determines the suitable response to the stimuli and decides how to reconfigure the system along with the SDR forms the CR. In the CR, the CE performs this task by using Artificial Intelligence (AI) techniques.
A CR takes action by configuring its transmission and receiving parameters to obtain a desired behavior that will accomplish a pre-determined goal or a set of goals. The actions that are executed center on two main activities. The first is shaping the transmission profile and configuring any pertinent radio parameters to use the resources given to the CR efficiently and simultaneously not interfere with the resources of other radios. The second action reshapes the transmission profile and reconfigures the parameters when the resources do change. The resources given to a CR are a set of frequencies, a set of time slots, and a set of antennas with beams pointed in different directions or any combination of these resources. The CE is the entity that ultimately decides which actions the CR must take.

ORGANIZATION OF THE BOOK

This handbook is divided into four sections: (1) radio spectrum sensing, (2) radio spectrum access and management, (3) software-defined radio and antennas for cognitive radio networks, and (4) models, security, and other related topics. Each section includes eight or nine chapters that offer basic research and case descriptions, as well as visionary ideas for future applications. The goal is to offer readers new insights on radio spectrum access and management issues and answer a broad array of questions related to these topics. Each section and chapter are briefly introduced next.

Radio Spectrum Sensing

This section describes the techniques related to radio spectrum sensing. Examples of topics covered include energy detection techniques, cooperative spectrum sensing with censoring of cognitive radios, tunable RF front-ends and robust sensing algorithms for cognitive radio receivers, energy-efficient partial-cooperative spectrum sensing in cognitive radio over fading channels, cyclostationary spectrum sensing, collaborative approaches for compressive spectrum sensing, spectrum sensing using principal components, and spectral sensing performance for feature-based signal detection with imperfect training.

Chapter 1: “Hybrid Cooperative Energy Detection Techniques in Cognitive Radio Networks”

An analysis of the Energy Detection (ED) test statistic is presented in this chapter. In addition, it identifies the general structure of ED threshold. Based on the double threshold ED, the authors analyze the performance of a Hybrid PSO-OR (Particle Swarm Optimization and OR) algorithm for cooperative spectrum sensing. The sensing decision of “fuzzy” secondary users is optimized using PSO and the final collective decision is made based on OR rule. The Hybrid PSO-OR algorithm is shown to exhibit significant performance gain over the Hybrid EGC-OR algorithm.

Chapter 2: “Cooperative Spectrum Sensing with Censoring of Cognitive Radios and MRC-Based Fusion in Fading and Shadowing Channels”

This chapter studies the performance of Cooperative Spectrum Sensing (CSS) with soft data fusion, given by Maximal Ratio Combining (MRC)-based fusion with Weibull-faded channels and log-normal
shadowed channels. The performance of CSS with two censoring schemes, namely rank-based and threshold-based, is studied in the presence of Weibull-fading and log-normal shadowing in the reporting channels, considering MRC fusion at fusion center.


The concepts of Cognitive Radio (CR) and multi-dimensional spectrum sensing are introduced in this chapter. Spectrum sensing methodologies, energy-efficiency consideration, resources scheduling, and self-management and learning mechanisms in cognitive radio networks are also discussed. The entailed challenges of CR RF front-end architectures are looked into. The synthesis and design performance analysis of a tunable RF front-end sensing receiver for CR applications are presented.

Chapter 4: “Energy-Efficient Cooperative Spectrum Sensing for Cognitive Radio Networks”

Energy efficiency in cooperative spectrum sensing in cognitive radio is investigated in this chapter. The proposed approach aims at reducing the energy consumed in spectrum sensing and improving the resultant energy efficiency of the cognitive transmission. The approach is based on limiting the number of users that participate in the spectrum-sensing task. The participation decision of each user is taken individually by the user itself, where each user compares the expected amount of consumed energy to a predefined threshold. The expected energy consumption is estimated at each user based on its distance from the base station.

Chapter 5: “Cyclostationary Spectrum Sensing in Cognitive Radios at Low SNR Regimes”

This chapter reviews non-cooperative cyclostationary sensing approaches and reports recent advances in cooperative cyclostationary sensing algorithms. New results for cooperative cyclostationary spectrum sensing are then presented, which ensure better performance and faster and simpler operation. In the proposed schemes, each Secondary-User (SU) performs Single-Cycle (SC) cyclostationary detection for fast and simple implementation, while collaboration between SUs in final decision on the presence or absence of the PU is explored to improve its performance. Illustrative and analytical results show that the proposed schemes outperform both SC and Multi-Cycle (MC) cyclostationary detectors, especially in fading channels.

Chapter 6: “A Collaborative Approach for Compressive Spectrum Sensing”

This chapter discusses the motivation and challenges of utilizing collaborative approaches for compressive spectrum sensing. The authors survey the different approaches and the key published results in this domain and present in detail an approach that utilizes Kronecker sparsifying bases to exploit the

xxxv
two-dimensional sparse structure in the measured spectrum at different, spatially separated cognitive radios. Simulation results show that the presented scheme can substantially reduce the Mean Square Error (MSE) of the recovered power spectrum density over conventional schemes while maintaining the use of a low-rate Sub-Nyquist Analog to Information Converter.

Chapter 7: “Spectrum Sensing Using Principal Components for Multiple Antenna Cognitive Radios”

Contrary to the previous work where the main evaluation technique has been theoretical analysis and simulations, this chapter uses Software-Defined Radios (SDRs) with correlated signal reception capability to evaluate the sensing performance of the existing Covariance-Based Detection (CBD) techniques. The existing techniques considered in this work include Covariance Absolute Value (CAV), Maximum-Minimum Eigenvalue (MME), Energy with Minimum Eigenvalue (EME), and Maximum Eigenvalue Detection (MED). This chapter also presents a novel technique for blind signal detection that uses Principal Component (PC) analysis.

Chapter 8: “Spectral Sensing Performance for Feature-Based Signal Detection with Imperfect Training”

Cognitive radio is a technique proposed to overcome the problem of high-required transmission data rate through wireless networks with limited available radio spectrum. Low latency and accurate spectral sensing by secondary users is crucial for effective cognitive radio implementation. This work characterizes the uncertainty of the imperfect training data in terms of the effect on training time and detection performance. The trade-off between training time and detection performance is determined. Spectrum sensing is implemented in a two-stage detector, which performs both feature training and sensing functions.

Chapter 9: “Sensing Orders in Multi-User Cognitive Radio Networks”

In multi-channel Cognitive Radio Networks (CRNs), an important challenge is to determine a sensing order for each Cognitive User (CU) so as to optimize a given performance metric. The sensing-order problem is compounded in multi-user CRNs where the multiple users in the network could collide with each other. With the focus on multi-user CRNs, this chapter uses cognitive-throughput maximization as the performance metric and describes how the optimal sensing orders can be computed for different contention management strategies used by the network.

Radio Spectrum Management and Access

This section relates to radio spectrum access and management. Topics covered include competition-based channel selection, routing through efficient channel assignment, spectrum management through trading, cooperative and non-cooperative access techniques, sensing order techniques in multi-user environment, competition-based channel selection methods, asynchronous channel allocation, distributed mechanisms for multiple-channel acquisition, channel and performance studies for spectrum-sharing, and game theoretic approaches.
Chapter 10: “On Fuzzy Logic-Based Channel Selection in Cognitive Radio Networks”

This chapter is reporting a fuzzy logic-based decision-making algorithm for competition-based channel selection. The underlying decision criterion integrates both statistics of licensed users’ channel occupancy and information about the competition level of unlicensed users. By using such an algorithm, the unlicensed user competitors can achieve an efficient sharing of the available channels. Simulation results are reported to demonstrate the performance and the effectiveness of the suggested algorithm.

Chapter 11: “Routing through Efficient Channel Assignment in Cognitive Radio Networks”

In this chapter, the authors focus on joint channel assignment and routing in cognitive radio networks, providing a comprehensive survey on routing and channel assignment in CRNs. First, the importance of joint channel assignment and routing for successful communication in cognitive radio networks is discussed. Then, classification and challenges related to channel assignment and routing are discussed in detail.


This chapter discusses various Dynamic Spectrum Management (DSM) algorithms, including Optimal Spectrum Balancing (OSB), Iterative Spectrum Balancing (ISB), Iterative Water-Filling (IWF), Selective Iterative Water-filling (SIW), Successive Convex Approximation for Low complEXity (SCALE), the Difference of Convex functions Algorithm (DCA), Distributed Spectrum Balancing (DSB), Autonomous Spectrum Balancing (ASB), and Constant Offset ASB using Multiple Reference Users (ASB-MRU). They are compared in terms of their performance (achievable data-rate) by extensive simulation results and their computational complexity.


This chapter investigates the performance of primary and secondary users in a spectrum-sharing cognitive environment. In this environment, multiple secondary users compete to share a channel dedicated to a primary user in order to transmit their data to a receiver unit. Only one secondary user is scheduled to share the channel, and to do so, the transmission power of the scheduled secondary user should satisfy the outage probability requirement of the primary user. Secondary users are ranked according to their channel strength, and performance measures are derived as a function of a generic channel rank.

Chapter 14: “Distributed Mechanisms for Multiple Channel Acquisition in a System of Uncoordinated Cognitive Radio Networks”

In this chapter, the authors consider a system of Cognitive Radio (CR) networks, where networks cannot communicate with one another and are incapable of implementing a specific and global communication protocol. They are concerned with the issue of coexistence in a decentralized system of CR networks.
The authors discuss channel acquisition mechanisms that can help CR networks maximize utility and minimize contention. The channel acquisition mechanisms are well suited for an uncoordinated system of CR networks. The mechanisms discussed here ensure fast convergence of the system by minimizing the contention experienced until a stable state of equilibrium is attained.

Chapter 15: “Asynchronous Channel Allocation in Opportunistic Cognitive Radio Networks”

The channel service quality, and the neighborhood discovery (NB) phase are fundamental and challenging due to the dynamics of cognitive radio networks. The authors provide an analysis of these challenges, controversies, and problems, and review the state-of-the-art literature. They show that, although recently there has been a proliferation of NB protocols, there is no optimal solution meeting all required expectations of cognitive radio users.


In this chapter, the authors first provide a systematic study on cooperative cognitive radio networking. As an effort to shed light on addressing spectrum-energy inefficiency at a low complexity, an orthogonal modulation-enabled two-phase cooperation framework and an orthogonally dual-polarized antenna-based framework, as well as their resource allocation problems, are given and tackled.


This chapter addresses the problem of throughput-efficient spectrum access in cognitive radio networks using coalitional game-theoretic framework. The authors model the problem of joint Coalition Formation (CF) and Bandwidth (BW) allocation as a CF game in partition form with non-transferable utility and present a variety of algorithms to dynamically share the available spectrum resources among competing Secondary Users (SUs). Performance analysis shows that the CF algorithms with optimal BW allocation provides a substantial gain in the network throughput over existing coalition formation techniques as well as the simple cases of singleton and grand coalition.


In this chapter, motivated by the recent advanced cognitive radio-enabled spectrum management schemes, the authors first summarize the current various advanced and flexible spectrum management schemes, including spectrum trading, leasing, pricing, and harvesting, and then analyze their advantages and disadvantages. Then, they take the viewpoints of both the spectrum marketing perspective and spectrum technical perspective, and they propose the centralized and distributed dynamic spectrum-sharing schemes, respectively.
Software-Defined Radio and Antennas for Cognitive Radio Networks

This third section describes novel antennas for cognitive radio networks as well as cognitive radio techniques and their implementation, using Software-Defined Radio technology. The topics covered include fundamentals of Software-Defined Radio and cooperative spectrum sensing, future reconfigurable radio front-ends for cognitive radio and Software-Defined Radio, precoder design for cognitive multiuser multi-way relay systems, reconfigurable antennas for flexible radio front-end, and complexity issues related to eigenvalue-based, multi-antenna spectrum sensing.


Cognitive Radio (CR) adapts itself to the newer environment on the basis of its intelligent sensing and captures the best available spectrum to meet user communication requirements. The performance of secondary systems could be enhanced by a Cooperative Spectrum Sensing (CSS) approach, as it increases the probability of detection of primary activities. This chapter is focused on software-defined radio, its architecture, limitations, then evolution to cognitive radio network, architecture of the CR, and its relevance in the wireless and mobile Ad-hoc networks.


A solid design of reconfigurable frontends, from the RF part to the digital baseband, should take into account different criteria to better exploit the available spectrum. In this chapter, architectures for the implementation and integration of future reconfigurable RF-frontends are presented. Furthermore, a general perspective to achieve smarter air interfaces is studied and discussed by setting out different strategies based on CR and SDR techniques.


This chapter discusses the design of precoders in cognitive multi-user multi-way relay systems. The authors discuss one possible solution of using a relay station as well as multiple antenna techniques. Precoding design in such a relay-supported multiple antenna secondary network is presented based on the Mean Square Error (MSE) design criterion. An iterative algorithm is proposed to iteratively optimize the precoding matrices at secondary transmitters, the precoding matrix at the secondary relay, and decoding matrices at secondary receivers. The design objective is to minimize the sum MSE of all received signals under transmit power constraints at each secondary transmitter as well as the relay station, while the interference to primary network is nulled out or kept under a certain level.

The aim of this chapter is to investigate possible roles that different categories of reconfigurable antennas can play in cognitive and smart radio. Hence, this chapter focuses on investigating some novel methods to frequency-reconfigure compact ultra-wideband antennas to work in different bands; this will offer additional filtering to the radio front-end. Furthermore, the design of novel pattern and polarization reconfigurable antennas will also be investigated to assist cognitive radio through spatial rather than frequency means.

Chapter 23: “Complexity Issues within Eigenvalue-Based Multi-Antenna Spectrum Sensing”

This chapter provides deep insight into multi-antenna eigenvalue-based spectrum-sensing algorithms from a complexity point of view. A review of eigenvalue-based spectrum-sensing algorithms is provided. The chapter presents a finite computational complexity analysis and a comparison of the Maximum to Minimum Eigenvalue (MME) detector and a simplified variant of the Multiple Beamforming detector as well as the approximated MME method. It is shown that the complexity/reliability tradeoff is a difficult challenge within spectrum sensing, given the strong requirements on sensing duration and detection performance.

Chapter 24: “Dual-Hop and Multi-Hop Cooperative Spectrum Sensing with an Improved Energy Detector and Multiple Antennae-Based Secondary Users”

A dual-hop cooperative spectrum-sensing approach is studied in detail, where each cooperative Cognitive Radio (CR) makes a binary decision based on the local observation, by using an improved energy detector, and then forwards it to a common receiver. At the common receiver, all binary decisions are fused together. The authors provide an analytical framework for the analysis of performance of the improved energy detector-based cooperative CR network.

Chapter 25: “Cognitive Radio Programming Survey”

Based on the authors’ analysis, the success of cognitive radio heavily depends on Software-Defined Radio (SDR). The cost, performance, and power consumption of SDR hardware platforms will enable (or forbid) smart radio applications and cognitive radio networks. SDR has evolved rapidly and is now reaching market maturity, but many issues have yet to be studied. In this chapter, the authors highlight how hardware architectures fulfill the constraints imposed by recent radio protocols, and they present current architectures and solutions for programming SDR. The authors also list the challenges to overcome in order to program future cognitive radio systems.
Chapter 26: “Cross-Layer Optimization and Link Adaptation in Cognitive Radios”

This chapter discusses the Adaptive Discrete Particle Swarm Optimization (ADPSO) algorithm as an efficient algorithm for optimizing and adapting CR operating parameters from physical, MAC, and network layers. In addition, the authors present two extensions for the proposed algorithm. The first one is Automatic Repeat reQuest-ADPSO (ARQ-ADPSO) for efficient spectrum utilization. The second one is merging ARQ-ADPSO and Case-Based Reasoning (CBR) algorithms for autonomous link adaptation under dynamic radio environment. The simulation results show improvements in the convergence time, signaling overhead, and spectrum utilization compared to the well-known optimization algorithms such as the Genetic Algorithm (GA).

Chapter 27: “Interference Statistics and Capacity-Outage Analysis in Cognitive Radio Networks”

This chapter presents a study on the interference caused by Secondary Users (SUs) due to miss-detection errors and its effects on the capacity-outage performance of the Primary User (PU) in a cognitive radio network assuming Rayleigh and Nakagami fading channels. The effect of beacon transmitter placement on aggregate interference distribution and capacity-outage performance is studied considering two scenarios of beacon transmitter placement: a beacon transmitter located at a PU transmitter and at a PU receiver. It is shown that the beacon transmitter at the PU receiver imposes less interference and, hence, better capacity-outage probability to the PU than the beacon transmitter at the PU transmitter.

Models, Security, and Other Related Topics

This section includes the chapters on modeling, security, pricing, and applications. The topics covered include modeling and performance evaluations, nonparametric Bayesian prediction of primary user air traffics, interacting particle system approaches, analysis of multiple cognitive radio networks and their coexistence, analysis of security issues and solutions, spectrum trading, competitive spectrum pricing under a centralized dynamic spectrum allocation, and applications of cognitive radio networks.

Chapter 28: “Modeling and Performance Evaluation”

In the literature, there are two methodologies: queuing theory/Markov chain-based analysis and stochastic network calculus-based analysis. These two methodologies rely on different mathematical basics and modeling approaches. Thus, they lead to different output metrics on various viewpoints. This chapter aims to give an overall introduction to both methodologies. First, the fundamental models used in queuing/Markov chain-based analysis will be presented, followed by its applications in cognitive radio networks. Then, network calculus basics are introduced with the modeling and application in performance analysis of the cognitive radio network.
Chapter 29: “Nonparametric Bayesian Prediction of Primary Users’ Air Traffics in Cognitive Radio Networks”

In cognitive radio networks, a secondary user needs to estimate the primary users’ air traffic patterns to optimize its transmission strategy. In this chapter, the authors describe a nonparametric Bayesian method for identifying and clustering traffic applications. In the proposed algorithm, the collapsed Gibbs sampler is applied to cluster the air traffic applications using the infinite Gaussian mixture model over the feature space of the packet length, the packet inter-arrival time, and the variance of packet lengths. The authors analyze the effectiveness of their proposed technique by extensive simulation using the measured data obtained from the WiMax networks.

Chapter 30: “Risk Engine Design as a Key Security Enhancement to the Standard Architecture for Cognitive Radio”

This chapter describes a risk engine that can incorporate a risk assessment cognition cycle. In various business sectors, risk management is the preferred mechanism to address unknown conditions and therefore offers promise in this context. The chapter describes how the risk engine can potentially address the vulnerabilities inherent to radio operation in the sensing/perception of spectrum, in the cognition cycle, or in the device infrastructure. It highlights some well-defined threats, their associated countermeasures, and suggests conceptual approaches for a risk engine to intervene in those scenarios.

Chapter 31: “Towards Security Issues and Solutions in Cognitive Radio Networks”

This chapter discusses the security issues in cognitive radio networks, and then it presents an intensive list of main known security threats in Cognitive Radio Networks (CRN) at various layers and the adverse effects on performance due to such threats, and the current existing paradigms to mitigate such issues and threats. Finally, the authors highlight proposed directions in order to make CRN more authenticated, reliable, and secure.

Chapter 32: “Heterogeneous Service-Oriented Spectrum Trading”

This chapter proposes an algorithm called HSO-ST (Heterogeneous Service-Oriented Spectrum Trading) with the target of maximum matching number under the priority restriction. This algorithm can satisfy more secondary users. Compared with other spectrum-trading strategies, HSO-ST can improve the spectrum demand-matching ratio greatly.

Chapter 33: “Exploiting Polarization for Spectrum Awareness in Cognitive Satellite Communications”

The authors firstly provide an overview of the existing works in polarization-based spectrum sharing. Secondly, they present the theoretical analysis of Energy Detection technique for dual polarized Additive White Gaussian Noise (AWGN) and Rayleigh fading channels considering the spectral coexistence
Preface

scenarios of dual and hybrid satellite systems. Finally, the authors provide the comparison of different combining techniques in terms of the sensing performance in the considered dual polarized channels with the help of theoretical analysis and numerical results.

Chapter 34: “Competitive Spectrum Pricing under Centralized Dynamic Spectrum Allocation”

This chapter models the dynamic spectrum allocation problem in wireless networks with a centralized spectrum broker, who manages “white space” in the spectrum of TV broadcasters in a given area and sells the vacant spectrum bands for revenue to multiple WSPs, as a multi-stage non-cooperative dynamic game. The simulation results show that the centralized spectrum allocation mechanism with dynamic pricing achieves a dynamic spectrum allocation implementation that is responsive to market conditions as well as enabling efficient utilization of the available spectrum.

Chapter 35: “Cognitive Radio Techniques for M2M Environments”

A new paradigm, called Cognitive Machine to Machine (CM2M) communications, has been recently considered to exploit cognitive/opportunistic radio communications. After having introduced the problem of applying cognitive techniques in M2M scenarios, the authors focus their attention on the Medium Access Control protocols for CM2M scenarios, with a particular attention on the OFDMA-based primary systems. Among other approaches, the authors focus on a data-aided approach for the access of the secondary devices, aiming to reduce the interference toward the primary system.

SUMMARY

Spectrum management and cognitive radio are new areas that span several fields, including information technology, computer science, computer engineering, and electrical engineering. Only a few books related to these areas have been published thus far. This book will be the first that covers all the concepts related to spectrum management and cognitive radio that are supported by the software that defines radio technology. It will provide timely, important technologies and methods of spectrum management and cognitive radio and be a valuable reference book for educators, researchers, practitioners, and graduate students.

The handbook covers a wide range of topics, including channel estimation and characterization, spectrum sensing, decision-making, antenna design, security in cognitive radio networks, and models. Books that cover all these topics are not currently available. This handbook offers a collection of engineering and computer science articles written by well-established researchers and industrials who have considerable expertise in cognitive radio, wireless communications, and electromagnetics.
Finally, this handbook is a timely contribution to assist researchers, students, engineers, educators, indeed anyone interested in radio spectrum, its management, and working in information technology, computer science, electrical engineering, and/or mechanical engineering. It offers chapters on current cutting-edge research into techniques, trends, and practical applications in the growing field of cognitive radio and radio spectrum management. It also discusses the most up-to-date research on radio spectrum sensing, access, management, security, models, antennas for cognitive radio networks, and their applications.

Naima Kaabouch  
*University of North Dakota, USA*

Wen-Chen Hu  
*University of North Dakota, USA*