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Preface

With the rapid development of broadband wireless communication techniques and increasing popularity of bandwidth-hungry multimedia applications, the industry faces significant challenge to meet the rapid expansion of wireless service requirements and users' Quality of Experience (QoE) due to the spectrum resource scarcity. On the other hand, there are widely witnessed low efficiency of static resource management mode, unbalanced spectrum resource distribution problem in real-world wireless networks, and additionally the distinguished resource acquisition abilities for distinguished wireless users. To address the related issues, dynamic spectrum sharing technologies have been leveraged as an effective approach to improve the wireless resource utilization and users' QoE for future broadband wireless networks, which is the focus of this book.

The book starts with an overview of the current state-of-the-art research literature about the efficient wireless resource utilization by leveraging the dynamic spectrum sharing technology. By utilizing spectrum access opportunities located in cellular frequency bands, a novel cognitive radio enabled dynamic overlay spectrum sharing framework with external sensors, i.e., external sensing agents, is developed. The opportunistic cellular frequency-band sharing is formulated as a dynamic resource demand–supply matching problem, and accordingly a fast distributed spectrum sharing algorithm is developed to solve the resource matching problem. Furthermore, WhiteFi Infostation is engineered, which is dedicated for Internet-based vehicular media streaming by leveraging Geolocation database enabled TV White Spaces (TVWS) spectrum sharing. After demonstrating the empirical observations of unique TV White Spaces spectrum features and analyzing the real-world TVWS data collected from Geolocation database, an optimal TVWS network planning is proposed for deploying WhiteFi Infostation with the objective of maximal network-wide throughput of TVWS sharing networks. The proposed TVWS network planning jointly considers the multi-radio configuration and the channel power tradeoff, which can be realized by decentralized Markov approximation. In addition, a location-aware contention-free multi-polling TV White Spaces access scheduling scheme is introduced for vehicular media streaming, which takes into account both the realistic vehicular application requirements and the dynamics of wireless channel conditions. Furthermore, the book investigates how to support the wireless multimedia networking applications while satisfying Quality of Services (QoS) guarantees by leveraging the dynamic TV White Spaces spectrum access technique. Accordingly, services with distinct secondary spectrum requirements are characterized and the resource bidding behaviors of secondary users are formulated based on their corresponding service classes, which can shed light on the design of practical bidding strategy for database-assisted TV White Spaces spectrum trading market. In addition, a double-phase dynamic spectrum allocation scheme is developed to support prioritized services such as real-time multimedia applications. In this way, better service can be provided to the secondary users with higher priority while achieving significant improvement of revenue. Finally, this book is closed with some open issues for further researches in next generation wireless access networks with the aim of efficient spectrum utilization.

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Contents

Acronyms

AP	Access Point
ARQ	Automatic Repeat Quest
BFF	Best First Fit
BS	Base Station
CA	Collision Avoidance
CDF	Cumulative Distributed Function
CDMA	Code Division Multiple Access
CFMP	Contention-Free Multi-Polling
CNMs	Cognitive Network Managers
CR	Cognitive Radio
CSMA	Carrier Sense Multiple Access
CT	Cognitive Terminal
CTMs	Cognitive Terminal Managers
CTS	Clear to Send
CWC	Cognitive Wireless Cloud
DCF	Distributed Coordination Function
DFSS	Distributed Fast Spectrum Sharing
DSA	Dynamic Spectrum Access
DSRC	Dedicated Short Range Communications
DSS	Dynamic Spectrum Sharing
ESM	Emergency Safety Message
ETSI	European Telecommunications Standards Institute
FBA	Frequency Band Aggregation
FCC	Federal Communications Commission
FSK	Frequency Shift Keying
FTM	Fluid Traffic Motion
GDD	Geolocation Database-Dependent
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force

ISM	Industrial Scientific Medical
ITS	Intelligent Transportation System
ITU-R	International Telecommunication Union-Radiocommunication Sector
JSP	Job-Shop Problem
LTE	Long-Term Evolution
MA	Mixed Aggregation
MAC	Media Access Control
MPDT	Multi-Polling Data Transmission
MPVU	Multi-Polling Vector Update
MSs	Mobile Stations
MU-MIMO	Multi-User Multiple-Input, Multiple-Output
MWC	Maximum Weight Clique
NB-OFDM	Narrow Band Orthogonal Frequency Division Multiplexing
NICT	National Institute of Information and Communications Technology
NRMs	Network Reconfiguration Managers
NRT	Non-Real Time
OBU	On-Board Unit
OFDM	Orthogonal Frequency Division Multiplexing
OSS	Open Spectrum Sharing
PCF	Point Coordination Function
PDF	Probability Density Function
PHY	Physical Layer
PUs	Primary Users
QoE	Quality of Experience
RANs	Radio Access Networks
RATs	Radio Access Technologies
RBs	Resource Blocks
RLSS	Registered Location Secure Server
RSU	RoadSide Unit
RTS	Request to Send
SDR	Software-Defined Radio
SIFS	Short Interframe Space
SINR	Signal-to-Interference-plus-Noise Ratio
SNR	Signal-to-Noise Ratio
SR	Status-Response
SRMP	Status-Request Multi-Polling
SSC	Spread Spectrum Communications
STAs	Stations
SUs	Secondary Users
TCP	Transmission Control Protocol
TFBs	Time–Frequency Blocks
TSA	Time Slot Aggregation
TV	Television
TVBDs	TV Band Devices

TVWS	TV White Spaces
UDP	User Datagram Protocol
UHF	Ultra-High Frequency
UWB	Ultra-Wide Band
V2I	Vehicle-to-Infrastructure
V2R	Vehicle-to-Roadside
V2V	Vehicle-to-Vehicle
VANET	Vehicular Ad hoc NETworks
VHF	Very High Frequency
W-CDMA	Wideband Code Division Multiple Access
WG	Working Group
WLAN	Wireless Local Area Networks
WPAN	Wireless Personal Area Network
WRAN	Wireless Regional Area Network
WSDs	White Space Devices

Chapter 1
Introduction

The ever increasing growth of wireless users' need for staying connected digitally and particularly the ubiquitous Internet access are attributing to the growth of bandwidth-hungry wireless applications, which creates a huge demand for wireless spectrum as well. Spectrum is the fundamental foundation of modern wireless networks. However, the currently existed wireless communication networks are mainly characterized by the static spectrum utilization policy, which leads to spectrum scarcity problem in wireless networks and significant challenge to support diverse bandwidth-hungry wireless applications in the foreseeable future. To break the spectrum scarcity bottleneck and enable the wireless connectivity with high Quality of Service (QoS) guarantee, dynamic sharing technology of wireless spectrum has been leveraged as an effective way to improve the spectrum utilization and improve the QoS of wireless users. Technically, dynamic spectrum sharing technology has received significant attentions since it can allow wireless users to dynamically share the allocated spectrum on a "do no harm" basis, which will lead to more efficient spectrum utilization without affecting the existing legacy systems.

The remainder of this chapter is organized as follows. In Sect. 1.1, we first introduce the related research background. In Sect. 1.2, we describe the basic concepts for dynamic sharing of wireless spectrum. Sections 1.3 and 1.4 discuss the research challenges of dynamic sharing of wireless spectrum and contributions of this Springer book, respectively. Section 1.5 introduces the organization of this book.

1.1 Background

Spectrum is a potentially scarce resource for the fast development of wireless network technologies. To well address the spectrum scarcity problem in specific geographical regions and certain spectrum bands and especially to improve the QoS requirements of wireless users [1–3], there are two types of emerging enabling dynamic sharing of wireless spectrum technologies, i.e., cognitive radio (CR) enabled dynamic spectrum

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sharing technology and database enabled dynamic spectrum sharing technology, which are given as follows:

- **CR enabled dynamic spectrum sharing technology**. Through self-adaptive and real-time interactions with the wireless environment, portions of the unused spectrum at a specific time or location can be identified/selected by users, shared with other users, and exploited without interference with licensed user [4]. In this way, CR enabled dynamic spectrum sharing technology can share the wireless spectrum resource in an opportunistic and self-adaptive manner [5, 6]. In addition, CR enabled wireless users are equipped with reconfigurable system devices, therefore, the best spectrum band and the most appropriate operating parameters can be selected and reconfigured by those wireless users.
- **Database enabled dynamic spectrum sharing technology**. Database enabled dynamic spectrum sharing technology requires to query a database to determine the spectrum availability and realize the dynamic sharing of wireless spectrum, which obviates the need of spectrum sensing [7, 8]. Currently, database enabled dynamic spectrum sharing technology mainly focuses on the TV broadcasting spectrum, i.e., TV White Spaces Spectrum [9]. In such a database assisted dynamic spectrum sharing architecture, the incumbents (primary licensed holders of TV spectrum-band) can provide the database with the up-to-date available spectrum information including TV receiver protection required transmission power parameters and TV tower transmission parameters.

In the following, we will present the related concepts for two main proposed enabling dynamic spectrum sharing technologies, respectively.

1.2 Basic Concepts

Cognitive radio enabled dynamic spectrum sharing technology has been coordinated by the Federal Communications Commission (FCC) for the radio spectrum resource usage and radio emission regulation [10]. For specific, The licensed spectrum holders are called Primary Users (PUs) while Secondary Users (SUs) are defined as the users who have no spectrum licenses but can dynamically utilize and access to the licensed spectrum on a "do no harm" basis [11]. IEEE 1900 projects release a serial of new standards in the areas of dynamic sharing of wireless spectrum research. Specially, concepts, architectures and approaches of cognitive radio enabled dynamic spectrum sharing have been extensively studied in the IEEE 1900.4 Working Group (WG) [12].

Figure 1.1 presents the concept of cognitive radio enabled dynamic spectrum sharing [13]. For specific, when different wireless access terminals would like to utilize the same frequency bands in the access networks, wireless access terminals can make realtime and adjustable spectrum usage rules by leveraging the cognitive radio enabled dynamic spectrum sharing technology to avoid the harmfully interfering each other in a negotiated or non-negotiated way. As shown in Fig. 1.1, we define