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# Spectrum Trading in Multi-Hop Cognitive Radio Networks

 Springer

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*To our families*



# Preface

Cognitive radio (CR) is a revolutionary wireless communication paradigm which releases the spectrum from shackles of authorized licenses and enables secondary users (SUs) to opportunistically access the underutilized licensed spectrum. Due to the great economic value of the spectrum, CR technology has also initiated the spectrum market and promoted a lot of interesting research on spectrum trading designs in cognitive radio networks (CRNs). However, existing spectrum trading approaches mainly focus on per-user-based spectrum trading for single-hop communications and lack deep understanding of multi-hop end-to-end service provision. Correspondingly, there is no such text exclusively on the spectrum trading in multi-hop CRNs today, leaving aspiring researchers and students in this field struggling with limited and scattered literature and sometimes confusing terminology. The goal of this book is to offer some help through accessible presentation of the basic ideas of spectrum trading as well as some related cutting-edge research of spectrum trading in multi-hop CRNs. The target audiences are researchers interested in CR technology and spectrum trading research, in particular graduate students. It is also our hope that this book can be useful to experts as quick reference.

This book starts with an introduction on spectrum trading, state-of-the-art research, and research challenges for spectrum trading in multi-hop CRNs. Then, a novel CRN network architecture tailored for spectrum trading in multi-hop CRNs is introduced. Under this CRN architecture, the transmission opportunity (i.e., a link-band pair)-based spectrum trading is presented, which is beyond the per-user-based spectrum trading in existing literature, and the proof of its economic robustness is provided. Further, this design is extended into session-based spectrum trading under uncertain spectrum supply, and finally an economic robust session-based spectrum trading design is developed and illustrated.

Some of the calculations and proofs involved are mathematical and can be safely skipped in first reading. Nevertheless, we decided to include them because they either illustrate useful analytical skills or provide details that are missing in the original papers. Due to the limited time, space, and of course our knowledge and ability, the content of this book is far from extensive. It only includes closely related literatures that we are mostly familiar with.

We would like to express our greatest appreciation to Dr. Xuemin (Sherman) Shen for providing us the opportunity of writing this short book for Springer. We are also grateful to all our collaborators and colleagues. Finally, we would like to thank Springer, especially Ms. Susan Lagerstrom-Fife, Ms. Jennifer Malat, Ms. Irene Bruce, and Ms. Courtney Clark, for their support in various aspects in the writing and publishing of this book. The book would not come into being without all those efforts and supports.

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# Contents

<b>1</b>	<b>The Network Architecture for Spectrum Trading</b>	1
1.1	Introduction to Spectrum Trading	1
1.1.1	From Static Spectrum Auction to Dynamic Spectrum Trading	1
1.1.2	State-of-Art Spectrum Trading Research	2
1.2	Research Challenges for Spectrum Trading	3
1.3	A Novel Network Architecture for Spectrum Trading in Multi-Hop CRNs	4
	References	6
<b>2</b>	<b>Economic-Robust Transmission Opportunity Based Spectrum Trading</b>	11
2.1	Problem Formulation	11
2.1.1	Network Model	11
2.1.2	Objective of TOST Design	13
2.1.3	Transmission Opportunity’s Capacity	13
2.2	Transmission Opportunity Based Spectrum Trading	14
2.2.1	Transmission Opportunity Allocation	14
2.2.2	Transmission Opportunity Scheduling	17
2.2.3	Pricing	18
2.3	Proof of Economic Properties	19
2.4	Performance Evaluation	23
2.4.1	Simulation Setup	23
2.4.2	Results and Analysis	23
	References	25
<b>3</b>	<b>A Session Based Spectrum Trading System Under Uncertain Spectrum Supply</b>	27
3.1	Network Model	27
3.1.1	Network Configuration	27
3.1.2	Other Related Models in Multi-Hop CRNs	28

3.2	Optimal Spectrum Trading Under Cross-Layer Constraints in Multi-Hop CRNs .....	29
3.2.1	Extended Conflict Graph, Cliques, and Independent Sets .....	30
3.2.2	CR Link Scheduling and Flow Routing Constraints .....	32
3.2.3	Optimal Spectrum Trading Under Multiple Constraints .....	34
3.3	The Upper Bound for the Session Based Spectrum Trading Optimization .....	35
3.4	A Bidding Value-Rate Requirement Ratio Based Heuristic Algorithm for Spectrum Trading .....	36
3.4.1	The BVR <sup>3</sup> Based Relax-and-Fix Algorithm .....	36
3.4.2	A Coarse-Grained Relax-and-Fix Heuristic Algorithm .....	39
3.5	Performance Evaluation .....	39
3.5.1	Simulation Setup .....	39
3.5.2	Results and Analysis .....	40
	References .....	45
<b>4</b>	<b>Economic-Robust Session Based Spectrum Trading .....</b>	<b>47</b>
4.1	Network Model .....	47
4.1.1	System Architecture for Spectrum Trading .....	47
4.1.2	Related Models in Multi-Hop CRNs .....	48
4.1.3	Preliminaries for Spectrum Trading .....	48
4.2	Optimal Resource Allocation for Session Based Spectrum Trading in Multi-Hop CRNs .....	49
4.2.1	Interference Constraints .....	49
4.2.2	Flow Routing Constraints .....	50
4.2.3	Problem Formulation .....	52
4.3	Economic-Robust Pricing Mechanism for Session Based Spectrum Trading .....	52
4.3.1	Pricing Mechanism .....	53
4.3.2	Proof of Economic-Robustness .....	54
4.4	Performance Evaluation .....	56
4.4.1	Simulation Setup .....	56
4.4.2	Results and Analysis .....	57
	References .....	59

# Acronyms

3-D	Three-dimensional
AWGN	Additive white Gaussian noise
BB	Budget balance
BIP	Binary integer programming
BVR <sup>3</sup>	Bidding value-rate requirement ratio
CR	Cognitive radio
CRN	Cognitive radio network
FCC	Federal Communications Commission
IC	Incentive compatibility
IR	Individual rationality
IS	Independent set
LBR	Link-band-radio
LP	Linear programming
MILP	Mixed-integer linear programming
MIS	Maximal independent set
PSP	Primary service provider
PU	Primary user
QoS	Quality of services
SSP	Secondary service provider
SU	Secondary user
TO	Transmission opportunity
TO-AL	Transmission opportunity allocation
TO-SC	Transmission opportunity scheduling
TOST	Transmission opportunity-based spectrum trading
VaR	Value at risk
VBG	Virtual bidder group