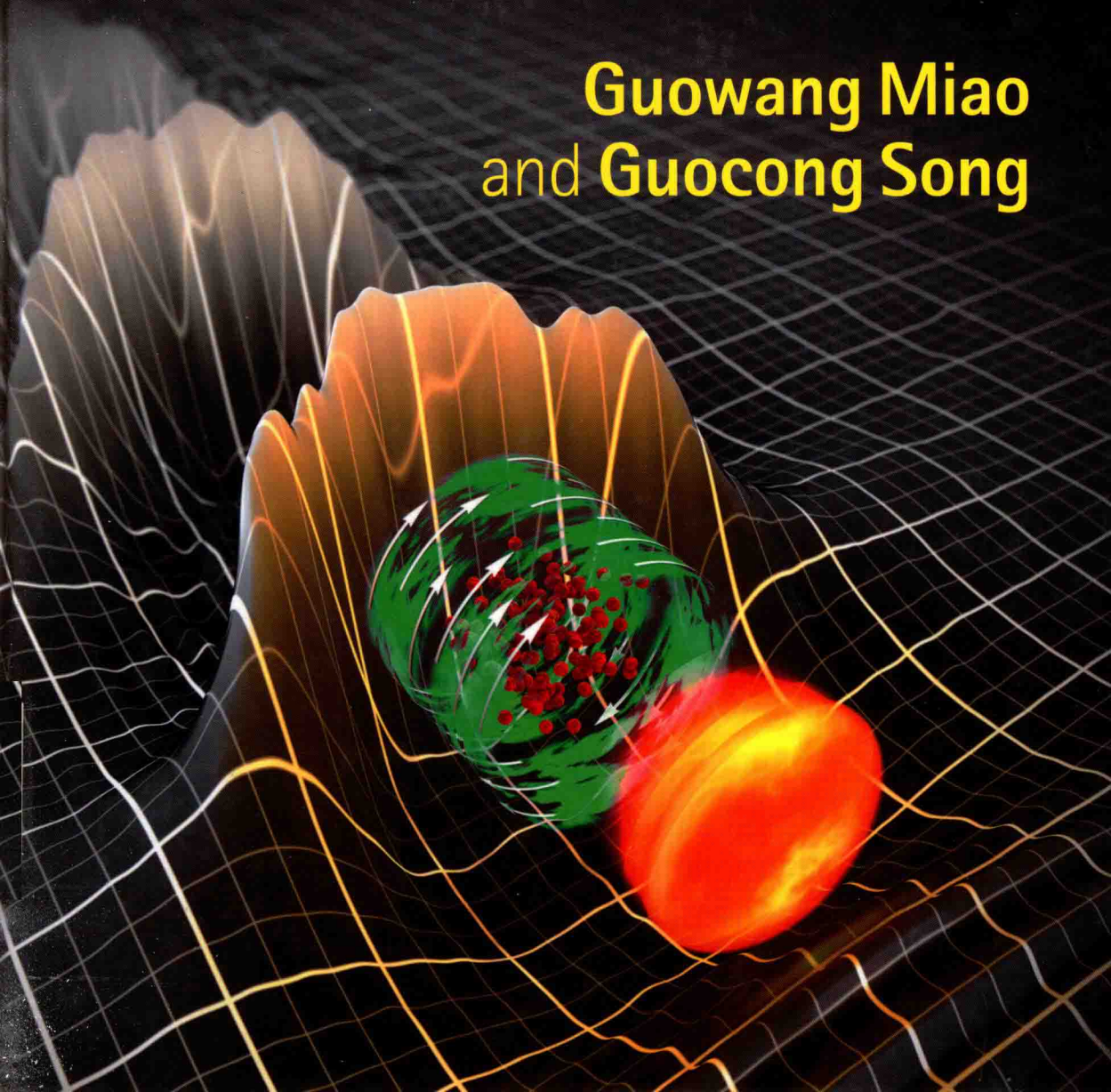


ENERGY AND SPECTRUM EFFICIENT WIRELESS NETWORK DESIGN

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Energy and Spectrum Efficient Wireless Network Design

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CAMBRIDGE
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University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781107039889

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First published 2015

Printed in the United Kingdom by Clays, St Ives plc

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Miao, Guowang.

Energy and spectrum efficient wireless network design / Guowang Miao, KTH Royal Institute of Technology, Sweden, Guocong Song, ShareThis, Palo Alto, California.

pages cm

ISBN 978-1-107-03988-9 (Hardback)

1. Wireless communication systems—Energy conservation. 2. Wireless communication systems—Energy consumption. 3. Radio frequency allocation. 4. Radio resource management (Wireless communications). 5. Engineering economy. I. Song, Guocong. II. Title.

TK5102.86.M53 2014

621.384—dc23 2014020418

ISBN 978-1-107-03988-9 Hardback

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Energy and Spectrum Efficient Wireless Network Design

Covering the fundamental principles and state-of-the-art cross-layer techniques, this practical guide provides the tools needed to design MIMO- and OFDM-based wireless networks that are both energy- and spectrum-efficient. Technologies are introduced in parallel for both centralized and distributed wireless networks to give you a clear understanding of the similarities and differences between their energy- and spectrum-efficient designs, which is essential for achieving the highest network energy saving without losing performance. Cutting-edge green cellular network design technologies, enabling you to master resource management for next-generation wireless networks based on MIMO and OFDM, and detailed real-world implementation examples are provided to guide your engineering design in both theory and practice. Whether you are a graduate student, a researcher, or a practitioner in industry, this is an invaluable guide.

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To
Ting Ren, Eileen Miao, and Ryan Miao
Wei and Lyra

Preface

This book provides a comprehensive introduction to the theory and practice of energy and spectrum efficient design for various types of wireless networks. The concepts and technologies are presented in a unified way for both centralized and distributed networks. The principles of the designs are stressed so that they can be applied in the broader context of wireless systems. The detailed derivations and proofs from first principles are provided. They are intended for the reader who desires a more in-depth understanding of the results. For the reader not interested in the detailed derivations, the concepts and theories are self contained and can be easily understood while skipping the derivations.

Energy and spectrum are two fundamental resources in wireless networks. A network design can always choose to optimize the utilization of one resource over the other. If one resource is redundant and the other is not, the design will need to optimize the network behavior towards better efficiency using that other resource. If both are adequate, then the system can be operated for the best user experience. If both are scarce, the design has to choose between them. Energy efficiency and spectrum efficiency are equally important and there is no clear advantage of one metric over the other. Which metric is more desired depends on network needs. This book presents a comprehensive yet rigorous discussion of the relationships between wireless channel state, energy efficiency, spectral efficiency, implementation, and network resource management in various wireless environments and their corresponding optimal designs.

The material in this book is structured into parallel discussions of energy and spectrum efficient designs, both of which are also discussed in parallel for centralized and distributed wireless networks. We hope this structure will facilitate the understanding of their similarities and distinctions.

The book is divided into four parts. In Part I, we introduce the basic concepts of wireless communications, e.g. wireless channel properties, performance metrics, conventional centralized and distributed radio resource management, that serve as the foundation to understand the book. The reader that is familiar with this background knowledge can skip this part and start from Part II directly. Part II introduces cross-layer designs for networks with central controllers and Part III for networks without central controllers. Both Parts II and III are focused on spectrum-efficient designs. Part II presents a generic framework for optimal opportunistic radio resource management in centralized networks by exploiting the multi-user diversity of time and frequency in

wireless channels and regulating the resource allocation through network economics. Part III covers how to optimally exploit multi-user diversity in distributed wireless networks and shows how distributed random access can be designed to achieve spectrum efficiency comparable to that of ideal centralized schedulers. In Part IV, we present optimal energy-efficient transmission and resource management for both centralized and distributed wireless networks. For example, while the Shannon capacity results tell us the tightest spectrum efficiency upper bound of point-to-point communications, we introduce the tightest energy efficiency upper bounds, named energy efficiency capacity, for various types of channels. We also introduce energy-efficient centralized scheduling and distributed medium access control (MAC) and power control. The relationships between energy efficiency, spectral efficiency, and several other network performance metrics are rigorously examined. At the end of this part, we give a thorough discussion on energy-efficient cellular network designs and also on how to implement energy-efficient designs in practice.

This book is highly recommended for graduate-level courses as the primary or alternate textbook and professional tutorials in wireless networks and resource management. It provides material both to guide novice students as well as plenty of detailed in-depth material for graduate students pursuing research in the field. The book is also a useful reference for practicing engineers, academics, and industrial researchers. The only expected background of the reader is a basic understanding of probability, optimization, and digital communications. Background in wireless networks, radio resource management, and signal processing is helpful but not required, since we develop the related material in the text.

Acronyms

3GPP	3rd Generation Partnership Project
AD	adjustment
AM	amplitude modulation
AP	access point
APA	adaptive power allocation
AWGN	additive white Gaussian noise
BER	bit error rate
BS	base station
C/I	carrier to interference
CAD-MAC	channel-aware distributed medium access control
CCI	co-channel interference
CDF	cumulative distribution function
CDMA	code division multiple access
CIA-MAC	co-channel interference avoidance MAC
CoMP	coordinated multi-point transmission
CRC	cyclic redundancy check
CRS	contention resolution slot
CSI	channel state information
CSMA	carrier sense multiple access
CSMA/CA	carrier sense multiple access with collision avoidance
CSMA/CD	carrier sense multiple access with collision detection
CTS	clear to send
DOMRA	decentralized optimization for multi-channel random access
DSA	dynamic subcarrier assignment
EMMPA	energy-efficient MU-MIMO power allocation
ESPA	exhaustive search power allocation
EXP	exponential
FCC	Federal Communications Commission
FDM	frequency division multiplexing
FDMA	frequency division multiple access
FEC	forward error correction
FFR	fractional frequency reuse
FFT	fast Fourier transform
FM	frequency modulation

FPA	fixed power allocation
FS	frequency selective
HOL	head-of-line
ICR	interference to carrier ratio
ICT	information and communication technology
IFFT	inverse fast Fourier transform
LDPC	low density parity check
LLC	logical link control
LOS	line of sight
LS	least squares
LTE	long-term evolution
MAC	medium access control
MCS	modulation and coding scheme
MDU	maximum delay utility
MIMO	multiple-input multiple-output
M-LWDF	modified largest weighted delay first
MMSE	minimum mean squared error
M-QAM	M-ary quadrature amplitude modulation
MSC	maximum sum capacity
MT	mobile terminal
MU-MIMO	multiple user MIMO
OFDM	orthogonal frequency division multiplexing
OFDMA	orthogonal frequency division multiple access
OSI	open systems interconnect
PA	power amplifier
PAPR	peak to average power ratio
PC	personal computer
PDF	probability distribution function
PER	packet error rate
PF	proportional fair
PHY	physical
PSK	phase shift keying
QoS	quality of service
RF	radio frequency
RNC	radio network controller
RTS	request to send
SDMA	space division multiple access
SIMO	single-input multiple-output
SINR	signal to interference plus noise ratio
SNR	signal-to-noise ratio
TDD	time division duplex
TDMA	time division multiple access
WFQ	weighted fair queueing
WLAN	wireless local area networks

Contents

	<i>Preface</i>	<i>page xv</i>
	<i>Acronyms</i>	<i>xvii</i>
1	Introduction	1
	1.1 Motivation	1
	1.2 Wireless networks	2
	1.2.1 Overview	2
	1.2.2 Traditional layered architecture	4
	1.2.3 Necessity of cross-layer optimization	6
	1.3 Book outline	8
Part I	Basic concepts	11
2	Wireless channel properties	15
	2.1 Path loss	15
	2.2 Shadowing	16
	2.3 Small-scale fading	17
	2.3.1 Flat-fading channels	18
	2.3.2 Frequency-selective fading channels	20
	2.4 Channel estimation	20
	2.4.1 Flat slow-fading channels	21
	2.4.2 Frequency-selective slow-fading channels	22
	2.4.3 Fast-fading channels	23
	2.4.4 Conclusion	23
	2.5 Other challenges	23
3	Spectral and energy efficiency of wireless networks	24
	3.1 Spectral efficiency	24
	3.2 Energy efficiency	25
	3.3 Link metrics versus network metrics	26

3.3.1	Link spectral efficiency	26
3.3.2	Network spectral efficiency	27
3.3.3	Link energy efficiency	29
3.3.4	Network energy efficiency	29
4	Centralized resource management in wireless networks	31
4.1	Overview	31
4.2	Wireless scheduling challenges	32
4.3	Centralized scheduling algorithms	34
4.3.1	Round-robin scheduling	35
4.3.2	Max throughput scheduling	36
4.3.3	Proportional fair scheduling	37
4.3.4	Max-min scheduling	38
4.3.5	Max utility scheduling	39
5	Distributed resource management in wireless networks	43
5.1	Overview	43
5.2	Aloha	45
5.2.1	Pure Aloha	45
5.2.2	Slotted Aloha	46
5.3	Carrier sense multiple access (CSMA)	46
5.3.1	Non-persistent CSMA	47
5.3.2	1-persistent CSMA	47
5.3.3	p-persistent CSMA	47
5.3.4	Effect of detection delay	47
5.4	CSMA with collision detection	48
5.5	Carrier sense multiple access with collision avoidance (CSMA/CA)	49
5.5.1	Hidden and exposed terminal problems	49
5.5.2	CSMA/CA protocol	50
Part II	Centralized cross-layer optimization	53
6	Overview	55
6.1	System model and problem description	56
6.1.1	Channel characteristics in OFDM	56
6.1.2	Rate adaptation in OFDM	58
6.1.3	Dynamic subcarrier assignment and adaptive power allocation	58
6.1.4	Queue structure	59
6.1.5	Problem description	59
6.2	Approach	59

7	Utility-based optimization framework for OFDMA	61
7.1	Rate-based utility functions	61
7.2	Theoretical framework	62
7.2.1	Problem formulation	62
7.2.2	Dynamic subcarrier assignment	63
7.2.3	Adaptive power allocation	66
7.2.4	Properties of cross-layer optimization	69
8	Algorithm development for utility-based optimization	72
8.1	Dynamic subcarrier assignment (DSA) algorithms	72
8.1.1	Optimality conditions	73
8.1.2	Sorting-search algorithm of subcarrier assignment	75
8.2	Adaptive power allocation (APA) algorithms	77
8.2.1	APA for fixed subcarrier assignment	77
8.2.2	Sequential-linear-approximation water-filling algorithm for continuous rate adaptation	78
8.2.3	Greedy power allocation algorithm based on maximizing total utility for discrete rate adaptation	78
8.3	Joint dynamic subcarrier assignment and adaptive power allocation	80
8.4	Algorithm modification for non-concave utility functions	81
8.5	Maximum utility with respect to average data rates	81
8.6	Efficiency and fairness	84
8.6.1	Fairness of “extreme OFDM” using utility functions with respect to instantaneous data rates	85
8.6.2	Fairness of “practical OFDM” using utility functions with respect to average data rates	85
8.7	Simulation results	87
8.8	Summary	93
9	Joint channel- and queue-aware multi-carrier scheduling using delay-based utility functions	94
9.1	Introduction	94
9.2	Extending scheduling rules in single-carrier networks into OFDMA networks	95
9.2.1	Max-sum-capacity (MSC) rule	95
9.2.2	Proportional fair (PF) scheduling	96
9.2.3	Modified largest weighted delay first (M-LWDF) rule	96
9.2.4	Exponential (EXP) rule	96
9.3	Max-delay-utility (MDU) scheduling	97
9.3.1	Utility functions	97
9.3.2	Optimization objective	97
9.3.3	Problem formulation in OFDMA	99

9.3.4	Algorithms	100
9.4	Stability	100
9.4.1	Background and definition of stability	100
9.4.2	Capacity region	101
9.4.3	Maximum stability region	102
9.5	Proof of Theorem 9.4	106
9.6	Further improvement through delay transmit diversity and adaptive power allocation	110
9.6.1	Joint dynamic subcarrier assignment and adaptive power allocation	110
9.6.2	Delay transmit diversity	111
9.7	Simulation results and performance comparison	112
9.7.1	Performance comparison	112
9.7.2	Improvement in delay transmit diversity and adaptive power allocation	116
9.8	Summary	116
10	Utility-based generalized QoS scheduling for heterogeneous traffic	117
10.1	Introduction	117
10.2	MDU scheduling for heterogeneous traffic	118
10.2.1	Mechanisms of MDU scheduling for diverse QoS requirements	118
10.2.2	Marginal utility functions for MDU scheduling	119
10.3	Simulation	120
10.3.1	Simulation conditions	120
10.3.2	Simulation results	121
10.4	Summary	125
11	Asymptotic performance analysis for channel-aware scheduling	126
11.1	Extreme value theory	126
11.2	Asymptotic throughput analysis of single-carrier networks	129
11.2.1	System model	129
11.2.2	Throughput analysis for Rayleigh fading	130
11.2.3	Throughput analysis for general channel distributions	133
11.2.4	Throughput analysis for normalized-SNR-based scheduling	136
11.2.5	Numerical results	138
11.3	Asymptotic delay analysis of single-carrier networks	139
11.3.1	Asymptotic distribution of service time	140
11.3.2	Average waiting time	141
11.4	Asymptotic performance analysis of multi-carrier networks	142
11.4.1	Asymptotic throughput analysis	142
11.4.2	Asymptotic delay analysis	143
11.4.3	Delay performance comparison	144
11.5	Summary	146

Part III	Distributed cross-layer optimization	147
12	Overview	149
	12.1 Design objective	149
	12.2 Distributed multi-user diversity	150
	12.3 Approaches	151
13	Opportunistic random access: single-cell cellular networks	154
	13.1 Channel-aware Aloha	154
	13.1.1 Protocol design and parameter optimization	157
	13.1.2 Performance analysis	159
	13.2 Opportunistic splitting algorithms	160
14	Opportunistic random access: any network topology	164
	14.1 Network model	164
	14.2 Optimal design rules	166
	14.2.1 MAC layer analysis	167
	14.2.2 Physical layer analysis	168
	14.2.3 Criterion for cross-layer design	169
	14.3 Low-complexity MAC	170
	14.4 Optimal PHY operation	173
	14.4.1 Physical layer optimization with channel inversion	173
	14.4.2 Physical layer optimization with adaptive modulation and power allocation	175
	14.5 System performance	178
	14.5.1 Network performance improvement	178
	14.5.2 Suboptimality gap	180
15	Optimal channel-aware distributed MAC	182
	15.1 System description	183
	15.2 Channel-aware medium access control	186
	15.3 Optimization	190
	15.3.1 CRS 1	191
	15.3.2 CRS k , $k > 1$	192
	15.4 Robustness analysis	195
	15.5 Simulation results	198
16	Opportunistic random access with intelligent interference avoidance	203
	16.1 Intelligent interferer recognition	204
	16.2 Co-channel interference avoidance MAC	206
	16.3 Parameter optimization	208

16.3.1	Trigger selection	208
16.3.2	An alternate trigger mechanism using location knowledge	210
16.4	Network performance	211
16.4.1	Relationship of trigger and SNR	212
16.4.2	Performance improvement	213
17	Distributed power control	217
17.1	System model	217
17.2	Power control for real-time traffic	218
17.2.1	Distributed power control	220
17.3	Power control for elastic traffic	221
17.3.1	Existence of equilibrium	224
17.3.2	Uniqueness of equilibrium in single-channel systems	225
17.3.3	Uniqueness of equilibrium in multi-channel systems	228
17.3.4	Distributed power control with pricing	231
Part IV	Cross-layer optimization for energy-efficient networks	235
18	Overview	237
18.1	Lighting analogy	238
18.2	Methodology	240
19	Energy-efficient transmission	244
19.1	Energy efficiency capacity	244
19.2	Ideal transmission	245
19.3	Energy-efficient transmission in practice	246
19.4	Energy-efficient link adaptation in frequency-selective channels	250
19.4.1	Modeling of energy-efficient link adaptation	252
19.4.2	Design principles	253
19.4.3	Constrained energy-efficient link adaptation	256
19.4.4	Energy-efficient downlink OFDMA transmission	257
19.4.5	Iterative algorithm design	258
19.4.6	Energy efficiency gain	262
19.5	Low-complexity energy-efficient link adaptation	263
19.6	Energy-efficient MIMO and MU-MIMO link adaptation	266
19.6.1	Energy-efficient MU-MIMO modeling	267
19.6.2	Principles of energy-efficient MU-MIMO power allocation	270
19.6.3	Energy-efficient MU-MIMO with improved circuit management	271
19.6.4	Energy efficiency gain	277
20	Centralized energy-efficient wireless resource management	282
20.1	Overview	282

20.1.1	Circuit component management	282
20.1.2	Time-domain resource management	283
20.1.3	Frequency-domain resource management	284
20.1.4	Spatial-domain resource management	284
20.2	Energy-efficient OFDMA in flat-fading channels	285
20.2.1	Resource allocation without fairness	287
20.2.2	Resource allocation with fairness	288
20.2.3	Performance comparisons	289
20.3	Energy-efficient scheduling in frequency-selective channels	291
20.3.1	Time-averaged network energy efficiency	292
20.3.2	Energy-efficient scheduler	294
20.3.3	Network performance	297
21	Distributed energy-efficient wireless resource management	301
21.1	Distributed energy-efficient MAC design	301
21.1.1	General rules of distributed MAC design	302
21.1.2	Impact of traffic load on energy consumption	304
21.2	Energy-efficient communications in special regimes	308
21.2.1	Circuit power dominated regime	309
21.2.2	Transmit power dominated regime	309
21.2.3	Noise dominated regime	310
21.2.4	Interference dominated regime	310
21.3	Distributed energy-efficient power control in frequency-selective channels	312
21.3.1	Non-cooperative energy-efficient power optimization game	313
21.3.2	Existence of equilibrium	314
21.3.3	Uniqueness of equilibrium in flat-fading channels	315
21.3.4	Uniqueness of equilibrium in frequency-selective channels	316
21.3.5	Conservative nature of power control	317
21.3.6	Spectral efficiency and energy efficiency improvement	318
22	Energy-efficient cellular network design	321
22.1	Fundamental tradeoffs in network resource utilization	321
22.1.1	Spectral and energy efficiency in single-user systems	322
22.1.2	Spectral and energy efficiency in multi-user systems with orthogonal selective channels	323
22.1.3	Spectral and energy efficiency in multi-user systems with interference channels	325
22.2	Energy-efficient homogeneous network deployment	327
22.3	Energy-efficient heterogeneous network deployment	330
22.4	Energy-efficient cellular network operation	332
22.4.1	Energy-efficient cell breathing	332

	22.4.2 Energy-efficient BS sleeping	332
	22.4.3 Cell size adaptation techniques	333
	22.4.4 Other energy-efficient designs	334
23	Implementation in practice	335
Appendix A	Proofs of Theorems and Lemmas	338
	References	355
	Index	365