

5G Green Mobile Communication Networks

Xiaohu Ge · Wuxiong Zhang

5G Green Mobile Communication Networks

 中国工信出版集团

 电子工业出版社
PUBLISHING HOUSE OF ELECTRONICS INDUSTRY
<http://www.phei.com.cn>

 Springer

Xiaohu Ge
School of Electronic Information
and Communications
Huazhong University of Science
and Technology
Wuhan, Hubei, China

Wuxiong Zhang
Shanghai Research Center
for Wireless Communications
Shanghai, China

ISBN 978-981-13-6251-4

ISBN 978-981-13-6252-1 (eBook)

<https://doi.org/10.1007/978-981-13-6252-1>

Jointly published with Publishing House of Electronics Industry, Beijing, China

The print edition is not for sale in China Mainland. Customers from China Mainland please order the print book from: Publishing House of Electronics Industry.

Library of Congress Control Number: 2019930643

© Publishing House of Electronics Industry, Beijing and Springer Nature Singapore Pte Ltd. 2019

This work is subject to copyright. All rights are reserved by the Publishers, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publishers, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publishers nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publishers remain neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.

The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Contents

1	Challenges of 5G Green Communication Networks	1
1.1	Introduction	1
1.2	Evolution of Green Communications	2
1.2.1	Computation Power	2
1.2.2	New Issues Triggered by the Computation Power	2
1.3	Computation and Communication Power in 5G Wireless Communication Systems	4
1.3.1	Power Consumption at BSs	4
1.3.2	Computation Power Model	5
1.3.3	Evaluations of Computation Power	11
1.3.4	Future Challenges	13
1.4	New Issues in 5G Green Cellular Networks	15
1.4.1	Computation Capability Factor	15
1.4.2	Heat Dissipation Factor	18
1.4.3	Maximum Receiving Rates for Smartphones	21
1.4.4	Simulation Results and Discussions	22
1.4.5	Future Challenges	24
1.5	Conclusions	25
	References	26
2	Energy Efficiency of 5G Wireless Communications	29
2.1	Introduction	29
2.2	Energy Efficient Hybrid Precoding Design	30
2.2.1	Related Work	30
2.2.2	System Model	32
2.2.3	Problem Formulation	34
2.2.4	Energy Efficient Hybrid Precoding Design	36
2.2.5	Energy Efficient Optimization with the Minimum Number of RF Chains	42

2.2.6	Simulation Results	50
2.2.7	Conclusions	54
2.3	Energy Efficient Optimization with RF Chains	55
2.3.1	Related Work	55
2.3.2	System Model	57
2.3.3	Problem Formulation	63
2.3.4	Hybrid Precoding Design for the Partially-Connected Structure	64
2.3.5	Simulation Results	71
2.3.6	Conclusions	76
2.4	Energy Efficient Power Control Scheme	78
2.4.1	Related Work	78
2.4.2	System Model	79
2.4.3	Achievable Rate of MIMO PVT Random Cellular Networks	81
2.4.4	Green MIMO Random Cellular Networks	85
2.4.5	Simulation Results	92
2.4.6	Conclusions	95
	References	96
3	Energy Efficiency of Cellular Networks	103
3.1	On the Energy-Efficient Deployment for Ultra-Dense Heterogeneous Networks with NLoS and LoS Transmissions	103
3.1.1	Introduction	103
3.1.2	System Model	105
3.1.3	Signal Propagation Model	105
3.1.4	Performance Analysis	109
3.1.5	Network Transformation	109
3.1.6	Performance Optimization and Tradeoff	115
3.1.7	Results and Insights	117
3.1.8	Conclusions and Future Work	125
3.1.9	Appendix	127
3.2	Spatial Spectrum and Energy Efficiency of Random Cellular Networks	132
3.2.1	Introduction	132
3.2.2	System Model	134
3.2.3	Models of PVT Random Cellular Networks	137
3.2.4	Spatial Spectrum and Energy Efficiency of PVT Random Cellular Networks	148
3.2.5	Conclusions	155
3.3	Energy Efficiency Optimization of 5G Full Duplex Cellular Networks: A Mean Field Game Approach	155

- 3.3.1 Introduction 155
- 3.3.2 System Model 157
- 3.3.3 Formulation of Energy Efficiency 158
- 3.3.4 Network Energy Efficiency Optimization 162
- 3.3.5 Algorithm Design of Mean Field Game 171
- 3.3.6 Numerical Simulations of Mean Field Game 172
- 3.3.7 Conclusion 178
- References 178
- 4 Energy Efficiency of 5G Multimedia Communications 185**
 - 4.1 Introduction 185
 - 4.2 Energy Efficiency Optimization for MIMO-OFDM Mobile
Multimedia Communication Systems with QoS Constraints 186
 - 4.2.1 Related Work 186
 - 4.2.2 System Model 188
 - 4.2.3 Energy Efficiency Modeling of MIMO-OFDM Mobile
Multimedia Communication Systems 189
 - 4.2.4 Energy Efficiency Optimization of Mobile Multimedia
Communication Systems 191
 - 4.2.5 Optimization Solution of Energy Efficiency 192
 - 4.2.6 Simulation Results and Performance Analysis 197
 - 4.2.7 Conclusions 203
 - 4.3 Multi-path Cooperative Communications Networks for
Augmented and Virtual Reality Transmission 204
 - 4.3.1 Related Work 204
 - 4.3.2 System Model 205
 - 4.3.3 Network Latency Model 208
 - 4.3.4 AR/VR Multi-path Cooperative Transmissions 215
 - 4.3.5 Service Effective Energy Optimization 220
 - 4.3.6 Simulation Results and Performance Analysis 223
 - 4.3.7 Conclusion 229
 - References 230
- 5 Wireless Resource Management for Green Communications 235**
 - 5.1 Introduction 235
 - 5.2 User Traffic Model 239
 - 5.2.1 Data Service 240
 - 5.2.2 Voice Service 242
 - 5.3 Downlink Average Rate and SINR Distribution in Cellular
Networks 247
 - 5.4 Bregman-Based Inexact Excessive Gap Method for Multiservice
Resource Allocation 251
 - 5.4.1 Problem Description 252
 - 5.4.2 Regularized Lagrangian Dual Function and δ -Excessive
Gap Smoothing Technique 254

5.4.3	Inexact Algorithm with Bregman Projection	258
5.4.4	Multi-service Resource Allocation Across Heterogeneous Networks	266
5.5	Conclusion	273
	Appendix 1	273
	Appendix 2	275
	Appendix 3	277
	Appendix 4	279
	References	283
6	Energy Efficiency and Collaborative Optimization Theory of 5G Heterogeneous Wireless Multi Networks	287
6.1	Introduction	287
6.1.1	Heterogeneous Wireless Multi-network Energy Efficiency Collaborative Optimization Architecture	290
6.1.2	Distributed Collaborative Architecture	290
6.1.3	Centralized Collaborative Architecture	290
6.1.4	Hybrid Collaborative Architecture	290
6.2	Power Reduction for Mobile Devices by Deploying Low-Power Base Stations	292
6.2.1	Current Energy Efficiency Metrics	292
6.2.2	A Novel Energy Efficiency Metric Jointly Considered by Networks and Terminals	294
6.2.3	Network Energy Efficiency Analysis in the Case of Macro and Micro Zone Coexistence	296
6.3	Wireless Network Virtualization and Software Defined Wireless Network	307
6.3.1	Wireless Virtualization	307
6.3.2	Software Defined Wireless Network	312
6.4	Conclusion	322
	References	323