

# Contents

<b>1</b>	<b>Quality of Service in Communication Systems</b>	<b>1</b>
1.1	Current Trends in End-to-End QoS in Cellular Networks	4
1.1.1	QoS in Wireless Networks	4
1.1.2	QoS in Wired IP Networks	8
1.2	Congested and Contested Spectrum	8
1.3	Network Quality of Service Challenges	10
1.4	Problem Statement	12
1.5	Book High Level Overview	15
1.6	Chapters Organization	16
	References	18
<b>2</b>	<b>Utility Functions and Radio Resource Allocation</b>	<b>21</b>
2.1	Application Utility Functions	22
2.2	Resource Allocation Formulations	25
2.2.1	Max-Min Resource Allocation	26
2.2.2	Proportional Fairness	26
2.2.3	Frank Kelly Algorithm	27
2.3	Previous Studies on Resource Allocation	27
2.4	Chapter Summary	29
2.5	MATLAB Code	30
	References	30
<b>3</b>	<b>Centralized Resource Allocation</b>	<b>37</b>
3.1	Resource Allocation Optimization	39
3.1.1	System Model	39
3.2	Centralized Architecture	43
3.3	Existence of Global Optimal Solution	44
3.4	Centralized Solution Algorithm	44
3.5	Centralized Architecture Simulation	46
3.5.1	Rate Allocation and Bids for $10 \leq R \leq 200$	48
3.6	Centralized Architecture Real-World Implementation	49
3.7	Chapter Summary	55

3.8	MATLAB Code . . . . .	56
	References. . . . .	59
<b>4</b>	<b>Distributed Resource Allocation . . . . .</b>	<b>61</b>
4.1	Distributed Architecture . . . . .	62
4.1.1	EURA Optimization Problem . . . . .	63
4.1.2	IURA Optimization Problem . . . . .	64
4.2	Distributed Architecture's Global Optimal Solution . . . . .	64
4.2.1	EURA Global Optimal Solution . . . . .	64
4.2.2	IURA Global Optimal Solution . . . . .	65
4.3	Distributed Solution Algorithm. . . . .	66
4.3.1	EURA Algorithm . . . . .	66
4.3.2	IURA Algorithm . . . . .	73
4.4	Mathematical Equivalence . . . . .	73
4.5	Distributed Architecture Simulation . . . . .	78
4.5.1	Rate Allocation and Bids for $10 \leq R \leq 200$ . . . . .	81
4.5.2	Pricing for $10 \leq R \leq 200$ . . . . .	83
4.6	Benchmark . . . . .	85
4.7	Chapter Summary . . . . .	86
4.8	MATLAB Code . . . . .	87
	References. . . . .	89
<b>5</b>	<b>Resource Allocation Architectures Traffic and Sensitivity Analysis . . . . .</b>	<b>93</b>
5.1	Traffic/Sensitivity Analysis Under UE Quantity Dynamics. . . . .	95
5.1.1	Distributed Architecture with Rebidding . . . . .	99
5.1.2	Distributed Architecture Without Rebidding . . . . .	101
5.1.3	Centralized Architecture . . . . .	103
5.2	Traffic/Sensitivity Analysis Under Application Usage Dynamics. . . . .	103
5.2.1	Distributed Architecture with Rebidding . . . . .	104
5.2.2	Distributed Architecture Without Rebidding . . . . .	105
5.2.3	Centralized Architecture . . . . .	107
5.3	Computational Complexity Considerations . . . . .	108
5.4	Traffic Analysis Simulation. . . . .	108
5.4.1	Transmission Overhead Analysis. . . . .	109
5.4.2	Sensitivity to Application Usage Changes . . . . .	110
5.4.3	Sensitivity to UE Quantity Changes . . . . .	113
5.5	Chapter Summary . . . . .	114
	References. . . . .	115
<b>6</b>	<b>Radio Resource Block Allocation . . . . .</b>	<b>117</b>
6.1	Introduction . . . . .	117
6.2	Continuous Optimization Relaxation. . . . .	120
6.2.1	Resource Block Optimization Formulation . . . . .	121
6.2.2	Relaxed Optimization . . . . .	122

6.3	Resource Block Optimization Solution Algorithm . . . . .	125
6.4	Resource Block Simulation Results . . . . .	128
6.4.1	Algorithm Convergence for $R = 50$ . . . . .	130
6.4.2	Algorithm Convergence for $50 \leq R \leq 100$ . . . . .	132
6.4.3	Resource Block Allocation . . . . .	135
6.5	Chapter Summary . . . . .	138
6.6	MATLAB Code . . . . .	139
	References. . . . .	145
<b>7</b>	<b>Spectrum-Shared Resource Allocation</b> . . . . .	<b>147</b>
7.1	Spectrum: A Congested and Contested Environments . . . . .	147
7.2	Architecture for Fair Allocation . . . . .	149
7.2.1	Congested Environment Radio Resource Allocation Optimization . . . . .	151
7.2.2	Solution Algorithm . . . . .	152
7.3	Practical Examples for Congested Environments and Resource Assignment. . . . .	154
7.4	Radar and LTE Systems. . . . .	156
7.4.1	Radar Simulation. . . . .	156
7.4.2	Macro Cell, Micro Cell, and Indoor LTE Simulation . . . . .	157
7.4.3	Propagation Model . . . . .	160
7.4.4	Radar Interference to Macro Cell LTE . . . . .	163
7.4.5	Radar to Outdoor Small Cell LTE UL Interference. . . . .	165
7.4.6	Radar Interference to Indoor Small Cell LTE . . . . .	166
7.5	Shared-Spectrum Resource Allocation . . . . .	166
7.6	Chapter Summary . . . . .	170
7.7	MATLAB Code . . . . .	171
	References. . . . .	177
<b>8</b>	<b>Delay-Based Backhaul Modeling</b> . . . . .	<b>179</b>
8.1	Introduction . . . . .	179
8.2	Theoretical Background . . . . .	180
8.2.1	Hidden Markov Processes . . . . .	181
8.2.2	Forward-Backward Algorithm. . . . .	181
8.2.3	Quantization . . . . .	183
8.3	System Model for Backhaul QoS . . . . .	184
8.3.1	Delay-Based HMP Modeling of Networks . . . . .	184
8.3.2	Quantization and Fidelity . . . . .	184
8.4	End-to-End QoS and Delay-Based Backhaul Modeling . . . . .	186
8.5	Experiments Results . . . . .	186
8.5.1	NS2 Experiments. . . . .	186
8.5.2	Internet Experiments . . . . .	189
8.5.3	Numerical Experiments . . . . .	191
8.6	Chapter Summary . . . . .	193
8.7	MATLAB. . . . .	193

8.7.1	Dataset Generation from ARM Processes . . . . .	194
8.7.2	Dataset Generation from NS2 . . . . .	194
8.7.3	LBG Quantization . . . . .	203
8.7.4	Uniform Quantization . . . . .	207
8.7.5	$\mu$ -Law Quantization . . . . .	208
8.7.6	Discrete Time Discrete Observation Bivariate HMP . . . . .	208
8.7.7	Discrete Time Discrete Observation Conventional HMP . . . . .	213
8.7.8	Discrete Time Exponential Observation HMP . . . . .	218
8.7.9	Discrete Time Discrete Observation Bivariate HMP Validation . . . . .	223
8.7.10	Discrete Time Discrete Observation Conventional HMP Validation . . . . .	231
8.7.11	Discrete Time Exponential Observation HMP Validation . . . . .	238
	References. . . . .	240
<b>9</b>	<b>Book Summary . . . . .</b>	<b>241</b>
9.1	Future Trajectory . . . . .	243
<b>Index</b>	<b>. . . . .</b>	<b>245</b>

Cellular Communications Systems in Congested  
Environments  
Resource Allocation and End-to-End Quality of Service  
Solutions with MATLAB  
Ghorbanzadeh, M.; Abdelhadi, A.; Ghorbanzadeh, M.  
2017, XVII, 247 p. 78 illus. in color., Hardcover  
ISBN: 978-3-319-46265-3