

# **RADIO RESOURCE MANAGEMENT FOR MULTIMEDIA QoS SUPPORT IN WIRELESS NETWORKS**

**Huan Chen**

**Lei Huang**

**Sunil Kumar**

**C.-C. Jay Kuo**

---

**KLUWER ACADEMIC PUBLISHERS**

---

# CONTENTS

<b>PREFACE</b>	<b>xi</b>
<b>ACKNOWLEDGEMENTS</b>	<b>xv</b>
<b>1 INTRODUCTION</b>	<b>1</b>
1.1 Quality of Service Issues in Wireless Multimedia Networks . . . . .	1
1.1.1 Multimedia Applications . . . . .	1
1.1.2 Wireless Networks . . . . .	2
1.2 Resource Management Issues in Cellular Wireless Systems . . . . .	4
1.2.1 Characteristics of Cellular Wireless Systems . . . . .	4
1.2.2 Resource Management . . . . .	6
BIBLIOGRAPHY . . . . .	7
<b>2 BACKGROUND</b>	<b>9</b>
2.1 Evolution of Wireless Communication Networks . . . . .	9
2.1.1 The First Generation (1G) Systems . . . . .	9
2.1.2 The Second Generation (2G) Systems . . . . .	9
2.1.3 The Third Generation (3G) Systems . . . . .	11
2.2 Challenges in Wireless Multimedia Networks . . . . .	12
2.2.1 Radio Aspect . . . . .	12
2.2.2 Network Aspect . . . . .	13
2.2.3 Other Aspects . . . . .	14
2.3 Challenges in Radio Resource Management . . . . .	15
2.3.1 Handoff and Mobility Issues . . . . .	15
2.3.2 Channel Assignment and Reservation . . . . .	16
2.3.3 Preferential Treatment . . . . .	16
2.4 QoS in Wireless Multimedia Networks . . . . .	18
2.4.1 Connection-level QoS . . . . .	19

---

2.4.2	Application-level QoS . . . . .	20
2.4.3	Related Work on QoS in Wireless Networks . . . . .	21
BIBLIOGRAPHY . . . . .		25
<b>3 ANALYSIS OF CONNECTION-LEVEL QOS</b>		<b>31</b>
3.1	Homogeneous Bandwidth Applications . . . . .	31
3.1.1	Non-priority Handoff Scheme . . . . .	33
3.1.2	Priority Handoff Scheme . . . . .	34
3.2	Heterogeneous Bandwidth Applications . . . . .	36
3.2.1	Non-priority Handoff Scheme . . . . .	38
3.2.2	Priority Handoff Scheme . . . . .	39
3.3	Rate-adaptive Applications . . . . .	41
3.3.1	Non-priority Handoff Scheme . . . . .	42
3.3.2	Priority Handoff Scheme . . . . .	45
3.4	Numerical Results . . . . .	47
3.4.1	Homogeneous Bandwidth Applications . . . . .	47
3.4.2	Heterogeneous Bandwidth Applications . . . . .	49
3.4.3	Rate-adaptive Applications . . . . .	51
3.5	Conclusion and Future Work . . . . .	60
BIBLIOGRAPHY . . . . .		64
<b>4 WIRELESS NETWORKS WITH ADAPTIVE RE-SOURCE MANAGEMENT</b>		<b>65</b>
4.1	Adaptive Resource Management System . . . . .	65
4.1.1	Service Model . . . . .	67
4.1.2	Application Profile . . . . .	72
4.1.3	Resource Allocation . . . . .	72
4.1.4	Rate-adaptive Applications . . . . .	75
4.2	Analysis for Connection-level QoS Service Model . . . . .	76
4.2.1	System with Handoff-guaranteed Service Class	76
4.2.2	System with Handoff-guaranteed and Handoff-prioritized Service Classes . . . . .	78
4.2.3	System with Three Service Classes . . . . .	79
4.3	Simulation and Discussion . . . . .	81
4.3.1	A Typical Scenario . . . . .	82
4.3.2	Varying Traffic Loads . . . . .	84
4.4	Conclusion and Future Work . . . . .	85

---

BIBLIOGRAPHY . . . . .	93
<b>5 DYNAMIC CALL ADMISSION CONTROL SCHEMES</b>	<b>95</b>
5.1 Dynamic CAC Schemes for CBR Traffic . . . . .	96
5.1.1 Problem Formulation . . . . .	96
5.1.2 Proposed Dynamic CAC Schemes . . . . .	97
5.1.3 Dynamic Channel Assignment Subject to Joint $P_B$ and $P_D$ Constraints . . . . .	104
5.2 Dynamic CAC Schemes for VBR Traffic . . . . .	106
5.2.1 VBR Traffic Model . . . . .	107
5.2.2 Problem Formulation . . . . .	109
5.2.3 Minimize $P_L$ Subject to $P_B$ and $P_D$ Constraints . . . . .	110
5.3 Simulation Results and Discussion . . . . .	111
5.3.1 Simulation Results for CBR Traffic . . . . .	111
5.3.2 Simulation Results for VBR Traffic . . . . .	116
5.4 Conclusion and Future Work . . . . .	118
BIBLIOGRAPHY . . . . .	125
<b>6 HANDOFF SCHEMES IN TDMA/FDMA SYSTEMS</b>	<b>129</b>
6.1 Fixed Guard Channel Handoff Scheme with Multiple Thresholds . . . . .	130
6.1.1 Service Model . . . . .	130
6.1.2 Proposed Multiple Thresholds GC Scheme . . . . .	131
6.1.3 Analytical Model . . . . .	131
6.2 Dynamic Guard Channel Handoff Scheme . . . . .	135
6.2.1 Mobile Simulation System . . . . .	135
6.2.2 Service Model and Application Profile . . . . .	140
6.2.3 Proposed Dynamic Guard Channel Scheme . . . . .	142
6.3 Simulation Results and Discussion . . . . .	147
6.3.1 Simulation Results for Fixed Guard Channel Handoff Scheme with Multiple Thresholds . . . . .	147
6.3.2 Simulation Results for Dynamic Guard Channel Scheme -Scenario I . . . . .	153
6.3.3 Simulation Results for Dynamic Guard Channel Scheme -Scenario II . . . . .	155

---

6.3.4	Conclusion and Future Work . . . . .	157
BIBLIOGRAPHY . . . . .		165
<b>7 HANDOFF SCHEMES IN CDMA SYSTEMS</b>		<b>167</b>
7.1	Introduction . . . . .	167
7.2	Overview of Capacity and Load Estimation in CDMA Systems . . . . .	170
7.3	Proposed IGM Scheme . . . . .	172
7.3.1	Service Model . . . . .	172
7.3.2	Resource Estimation and Reservation in IGM Scheme . . . . .	173
7.3.3	Dynamic Resource-Reservation Estimation . . . . .	174
7.3.4	Call Admission Control Algorithm . . . . .	177
7.4	Simulation Results . . . . .	180
7.4.1	System Model and Link Characteristics . . . . .	180
7.4.2	Non-rate Adaptive Traffic . . . . .	182
7.4.3	Rate Adaptive Traffic . . . . .	182
7.4.4	System Utilization . . . . .	183
7.5	Conclusion and Future Work . . . . .	184
BIBLIOGRAPHY . . . . .		188
<b>8 RADIO RESOURCE MANAGEMENT WITH MDP</b>		<b>191</b>
8.1	Introduction to MDP and CAC Policy . . . . .	191
8.1.1	System Capacity in Interference-limited Systems	194
8.1.2	MDP and Optimal CAC Policy . . . . .	196
8.1.3	Markov Decision Process Model . . . . .	197
8.1.4	Uniformization Technique . . . . .	199
8.1.5	Solution via Linear Programming . . . . .	201
8.2	2-D MDP and Optimal CAC Policy in Homogeneous Handoff Systems . . . . .	203
8.2.1	System Model . . . . .	203
8.2.2	Modified Linear Programming . . . . .	206
8.3	3-D MDP and Optimal CAC Policy . . . . .	206
8.3.1	System Model . . . . .	206
8.3.2	Solution via Linear Programming . . . . .	208
8.4	Simulation Results and Discussion . . . . .	210

---

8.4.1	Numerical Results for 2-D CAC Policy using MDP . . . . .	210
8.4.2	Numerical Results for 3-D CAC Policy using MDP . . . . .	223
8.5	Complexity of the MDP using Linear Programming Approach . . . . .	231
8.5.1	Complexity Issue for Linear Programming . . . . .	234
8.5.2	Derivation of the Problem Size . . . . .	237
8.5.3	Conclusion and Future Work . . . . .	241
	BIBLIOGRAPHY . . . . .	242
<b>9</b>	<b>FUTURE TRENDS</b>	<b>245</b>
9.1	Summary of Research . . . . .	245
9.1.1	Wireless QoS Research . . . . .	245
9.1.2	Resource Management Research . . . . .	246
9.2	Future Work . . . . .	248
9.2.1	Connection-level and Packet-level QoS for VBR traffic . . . . .	248
9.2.2	Embedded System Design for Resource Man- agement . . . . .	249
	BIBLIOGRAPHY . . . . .	252
	<b>INDEX</b>	<b>253</b>