

TABLE OF CONTENTS

Dedication	v
Table of Contents	vii
Preface	xvii
Chapter 1 Overview of Wireless Networks	
1.1 Signal Coverage	1
1.2 Propagation Mechanisms	2
1.2.1 Multipath	2
1.2.2 Delay Spread	3
1.2.3 Coherence Bandwidth	4
1.2.4 Doppler Spread	5
1.2.5 Shadow Fading	6
1.2.6 Radio Propagation Modeling	6
1.2.7 Narrowband and Wideband Channel Models	6
1.3 Signal Attenuation	7
1.3.1 Received Power Characteristics	7
1.3.2 High Frequency Propagation	8
1.4 Channel Characteristics	9
1.4.1 Gaussian Channel	9
1.4.2 Rayleigh Channel	9
1.4.3 Rician Channel	10
1.5 Fading Mitigation Methods	10
1.5.1 Antenna Diversity	11
1.5.2 Equalization	11
1.5.3 Error Control	13
1.5.4 Multicarrier Transmission	13
1.5.5 Orthogonal Frequency Division Multiplexing	14
1.5.6 Wideband Systems	15
1.6 Interference	15
1.6.1 Cochannel Interference	16
1.6.2 Mitigation Techniques	17
1.7 Modulation	17
1.7.1 Linear versus Constant Envelope	17
1.7.2 Coherent versus Non-Coherent Detection	18

1.7.3 Multicarrier Modulation	19
1.8 Signal Duplexing Techniques	20
1.8.1 Spectrum Considerations	20
1.8.2 Radio Design Considerations	20
1.8.3 Implementation Considerations	21
1.9 Mobility and Handoff	21
1.9.1 Intracell versus Intercell Handoff	22
1.9.2 Mobile-Initiated versus Network-Initiated Handoff	22
1.9.3 Forward versus Backward Handoff	23
1.9.4 Hard versus Soft Handoff	23
1.10 Channel Assignment Strategies	24
1.11 Synchronization	24
1.12 Power Management	25
1.13 Spectrum Allocation	25
Summary	26
Bibliography	27

Chapter 2 Wireless Access Protocol Design

2.1 Traffic Source Characterization	31
2.1.1 Periodic Traffic	31
2.1.2 Bursty Traffic	33
2.2 Characterizing Applications	34
2.2.1 Information Types	34
2.2.2 Delivery Requirements	34
2.2.3 Symmetry of Connection	35
2.2.4 Communication Requirements	35
2.2.5 Broadband Services	35
2.3 Resource Sharing	36
2.3.1 Resource Sharing Principles	36
2.3.2 The Global Queue	37
2.3.3 Measuring Resource Usage	38
2.3.4 Resource Sharing in Wideband Wireless Networks	38
2.3.5 Resource Reservation and Application Adaptation	39
2.3.6 Admission Control	39
2.4 Performance Analysis	40
2.5 Performance Evaluation	41
2.5.1 Efficiency	42
2.5.2 Throughput	42

2.5.3 Response Time	43
2.5.4 Fairness	43
2.6 Implementation Considerations	43
2.6.1 Centralized versus Distributed Design	43
2.6.2 Mobility versus Portability	44
2.6.3 Integration with Higher Layer Functions	45
Summary	45
Bibliography	45

Chapter 3 Multiple Access Communications

3.1 Characterizing the Access Problem	49
3.1.1 General Characteristics	50
3.1.2 Classification	50
3.2 Framework for Discussion	52
3.2.1 General Network Assumptions	53
3.2.2 Collisions	53
3.2.3 User Population	54
3.2.4 Propagation Delay	55
3.2.5 Channel Feedback	55
3.2.6 Full and Limited Sensing	56
Summary	57
Bibliography	57

Chapter 4 Fixed Allocation Access Protocols

4.1 Frequency Division Multiple Access	61
4.1.1 Disadvantages	62
4.1.2 Implementation	62
4.2 Time Division Multiple Access	62
4.2.1 Disadvantages	63
4.2.2 Implementation	64
4.3 Comparison of FDMA and TDMA	64
4.4 Performance Evaluation	65
4.4.1 Frequency Division Multiple Access	65
4.4.2 Time Division Multiple Access	66
4.4.3 Statistical Multiplexing	68

4.5 Polling Protocols	69
4.5.1 Performance Analysis	70
4.5.2 Probing	71
4.5.3 Adaptive Probing	72
4.6 Service Disciplines in Polling Systems	73
Summary	73
Bibliography	74

Chapter 5 Contention Protocols

5.1 General Characteristics	77
5.2 ALOHA Protocols	78
5.2.1 Unslotted ALOHA	78
5.2.2 Slotted ALOHA	79
5.2.3 Disciplined ALOHA	80
5.2.4 Spread ALOHA	81
5.3 Performance Analysis of ALOHA Protocols	81
5.3.1 Throughput Analysis	82
5.3.2 Average Number of Retransmissions	84
5.3.3 Acknowledgments	85
5.3.4 Power Capture	86
5.3.5 Analyzing the Slotted ALOHA Protocol with Capture	86
5.3.6 Controlled ALOHA	88
5.3.7 Asymmetric Traffic Load	88
5.3.8 Scheduling Retransmissions	90
5.3.9 Delay Analysis	93
5.4 Stability Problems in ALOHA Protocols	94
5.4.1 Stability Characterization	95
5.4.2 Dynamic Controls	96
5.5 Feedback Algorithms	96
5.5.1 The Binary Tree Algorithm	97
5.5.2 Analyzing the Tree Algorithm	97
5.5.3 Improving the Tree Algorithm	100
5.5.4 The Splitting Algorithm	101
5.5.5 Implementation Considerations	102

5.6	Carrier Sense Multiple Access	103
5.6.1	CSMA Variations	103
5.6.2	Performance Considerations	104
5.6.3	Implementation Considerations	105
5.6.4	CSMA with Collision Detection	106
5.6.5	Virtual-Time CSMA	107
5.6.6	Busy Tone Multiple Access	108
5.7	Adaptive Protocols	108
5.7.1	The URN Protocol	108
5.8	Hybrid Access Protocols	109
5.8.1	Split Reservation Upon Collision	110
5.8.2	Mixed ALOHA Carrier Sense	110
5.8.3	Random Access Polling	110
	Summary	111
	Bibliography	111

Chapter 6 Spread Spectrum Multiple Access

6.1	Spread Spectrum Communications	119
6.2	Wideband Versus Narrowband	121
6.2.1	Code Division	121
6.2.2	Time Capture	121
6.2.3	Collisions in SSMA Systems	122
6.3	Direct Sequence Spread Spectrum	123
6.3.1	Processing Gain	124
6.3.2	Direct Sequence Code Division Multiple Access	124
6.3.3	Power Control	127
6.3.4	Synchronization	128
6.3.5	RAKE Receiver	128
6.3.6	Benefits of DSSS	129
6.4	Frequency Hopped Spread Spectrum	130
6.4.1	Slow and Fast FH	130
6.4.2	Benefits FHSS	131
6.5	Spreading Code Protocols	132
6.5.1	Common Code	132
6.5.2	Transmitter-Directed Codes	132
6.5.3	Receiver-Directed Codes	132
6.5.4	Single Code for Pairs of Users	133

6.6	CDMA Network Design	133
6.6.1	Multirate CDMA	133
6.6.2	CDMA Receivers	134
6.6.3	Multiuser Detection	134
6.6.4	Interference Cancellation and Suppression	135
6.6.5	Multicarrier CDMA	135
6.7	Performance Analysis	136
6.7.1	Queuing Theory Modeling	136
6.7.2	Estimating the Number of Users in DS-CDMA	137
6.8	Comparing FDMA, TDMA, and CDMA	139
6.8.1	Advantages of CDMA	139
6.8.2	Disadvantages of CDMA	141
	Summary	142
	Bibliography	142

Chapter 7 Reservation Protocols

7.1	General Characteristics	147
7.2	Centralized and Distributed	148
7.3	Reservation-ALOHA	148
7.3.1	Implementation Considerations	149
7.3.2	Performance Considerations	149
7.4	Packet Reservation Multiple Access	150
7.5	Dynamic Reservation	151
7.5.1	Implementation Considerations	152
7.5.2	Performance Considerations	152
7.6	Dynamic Reservation Multiple Access	153
7.7	Round-Robin Reservation Scheme	154
7.8	Split-Channel Reservation Multiple Access	154
7.9	Integrated Access Scheme	155
7.10	Demand Access Multiple Access	155
7.11	Priority-Oriented Demand Assignment	156
7.12	Announced Retransmission Random Access	157
7.13	Minislotted Protocols	157
7.14	Bit Map Access Protocol	158
7.15	Broadcast Recognition Access Method	158
7.16	Multilevel Multiple Access	159
	Summary	159
	Bibliography	160

Chapter 8 **Broadband Wireless Access Protocols**

8.1	The 2.4 GHz IEEE 802.11 Wireless LAN Standard	165
8.1.1	The Distributed Coordination Function	166
8.1.2	Virtual Sensing	168
8.1.3	The Point Coordination Function	170
8.2	The 5 GHz IEEE 802.11 Wireless LAN Standard	171
8.3	The HIPERLAN Type 1 Wireless LAN Standard	172
8.3.1	The EY-NPMA MAC Protocol	172
8.3.2	Quality of Service	175
8.4	The HIPERLAN Type 2 Wireless LAN Standard	175
8.4.1	HIPERLAN Type 2 MAC Protocol	176
8.4.2	HiperLAN Type 2 Frame Format	177
8.4.3	QoS support	178
8.5	Home Networks	179
8.5.1	HomeRF's Shared Wireless Access Protocol	179
8.5.2	Bluetooth's Access Mechanism	180
8.6	Wireless ATM	181
8.6.1	Simple Asynchronous Multiple Access	181
8.6.2	Distributed Queuing Request Update Multiple Access	182
8.6.3	MASCARA	183
8.6.4	WATMnet Access Protocol	184
8.6.5	AWACS Access Protocol	185
8.7	Satellite ATM	187
8.7.1	Multibeam Systems	187
8.7.2	Multifrequency TDMA	188
8.8	Wireless Local Loop	189
8.8.1	MMDS	189
8.8.2	LMDS	190
8.8.3	Access Methods in LMDS	190
8.9	IMT-2000	190
8.9.1	Coverage Areas and Data Rates	191
8.9.2	CDMA Proposals	191
8.9.3	Wideband CDMA	192
8.9.4	Time-Duplexed CDMA	193
8.9.5	CDMA2000	193
8.9.6	TDMA Proposals	194
	Summary	195
	Bibliography	195

Chapter 9 A Generalized Broadband Wireless Access Protocol

9.1 Protocol Description	199
9.2 Protocol Evaluation	203
9.3 Analysis of Randomized Slotted ALOHA	204
9.3.1 Throughput Analysis	205
9.3.2 Stability Analysis	206
9.4 Analysis of the Generalized Protocol	211
9.4.1 Throughput Analysis	212
9.4.2 Delay Analysis	214
9.5 Performance Comparison	221
9.6 Traffic Load Balancing	223
9.6.1 Protocol Description	226
9.6.2 Simulation Results	229
9.7 OPNET Simulation Models	232
9.8 OPNET Models for Generalized Protocol	233
9.8.1 User Model for Base Station	233
9.8.2 User Model for User with Periodic Traffic	234
9.8.3 Process Model for Base Station	234
9.8.4 Process Model for User with Periodic Traffic	236
9.9 OPNET Models for Traffic Load Balancing	238
9.9.1 User Model for Base Station	239
9.9.2 User Model for User with Periodic Traffic	239
9.9.3 Process Model for Base Station	239
9.9.4 Process Model for User with Periodic Traffic	239
9.10 Simulation Time	240
9.11 Formal Verification of Generalized Protocol	240
9.11.1 Correctness	241
9.11.2 Safety	241
9.11.3 Liveness	242
Summary	243
Bibliography	244

Appendix Queuing Theory Primer

A.1 The Poisson Process	247
A.2 Little's Theorem	248
A.3 The Single Server Queue	249
A.3.1 M/G/1 Queue	250

A.3.2 M/M/1 Queue	251
A.3.3 M/D/1 Queue	251
A.4 Conservation Laws	252
Acronyms	253
About the Author	259
Index	261