

CONTENTS

Preface	ix
PART I QUEUEING NETWORK MODELS WITH BLOCKING AND APPLICATIONS	
1. Introduction	3
1.1 Commonly used probability distributions	4
1.2 Analysis of a single queue	6
1.3 Queueing networks	8
1.3.1 Product form solutions and BCMP theorem	9
1.3.2 Numerical solutions	12
1.3.3 Simulation	12
1.3.4 Approximate solutions	13
1.3.5 Performance metrics	13
1.4 Queueing networks with finite capacity queues	15
1.5 Bibliographical notes and references	16
1.5.1 Books on queueing theory and queueing systems	16
1.5.2 Surveys, tutorials and books on queueing networks with blocking	17
1.5.3 Publications on queueing networks	17
2. Queueing networks with blocking	25
2.1 Single class networks	25
2.2 Blocking mechanisms	28
2.3 Blocking and state dependent routing	35
2.4 Multiclass queueing networks with finite capacity queues	35
2.5 Performance indices	37
2.6 Bibliographical notes	43
References	45
3. Application examples of queueing networks with blocking	51
References	59
PART II ANALYSIS OF QUEUEING NETWORKS WITH BLOCKING	
4. Exact analysis of Markovian networks	63
4.1 The Markov process as the network model	63
4.1.1 Repetitive Service Blocking - Random Destination	65
4.1.2 Repetitive Service Blocking - Fixed Destination	67

4.1.3	Blocking After Service	68
4.1.4	Blocking Before Service - Server Occupied	73
4.1.5	Blocking Before Service - Server Not Occupied	77
4.1.6	Blocking Before Service - Overall	78
4.1.7	A simple example	80
4.1.8	Stop and Recirculate Blocking	83
4.1.9	Heterogeneous networks	86
4.2	Queue length distribution and average performance indices	89
4.3	Arrival time distribution	95
4.4	Cycle time distribution	97
4.5	Bibliographical notes	99
	References	101
5.	Exact analysis of special networks	103
5.1	Product form networks	103
5.1.1	Product form solution of the joint queue length distribution	104
5.2	Algorithms for product form networks	110
5.2.1	Convolution algorithm	111
5.2.2	Performance indices	120
5.3	Symmetrical networks	123
5.3.1	Solution reduction technique	125
5.3.2	Performance indices	129
5.4	Arrival theorem	134
5.5	Bibliographical notes	136
	References	138
6.	Approximate and bound analysis	143
6.1	Introduction	143
6.2	Approximate analysis of closed networks	145
6.2.1	Approximate methods for cyclic networks	147
6.2.2	Approximate methods for arbitrary topology networks	154
6.3	Approximate analysis of open networks	158
6.3.1	Approximate methods for tandem networks	158
6.3.2	Approximate methods for acyclic and arbitrary topology networks	163
6.4	Bound analysis	168
6.5	Bibliographical notes	170
	References	172
 PART III PROPERTIES OF NETWORKS WITH BLOCKING		
7.	Equivalence, insensitivity and monotonicity properties	179
7.1	Equivalence properties: state distribution and average performance	180

Contents	vii
indices	
7.1.1 Special equivalences	181
7.1.2 Equivalences between networks with and without blocking	183
7.1.3 Equivalences between different blocking types	184
7.2 Equivalence properties: passage time distribution	195
7.3 Equivalence properties: fork/join networks	196
7.4 Insensitivity	201
7.5 Monotonicity	202
7.5.1 Performance comparison of blocking symmetrical networks	203
7.6 Bibliographical notes	211
References	213
8. Buffer allocation in queueing networks with finite capacities	217
8.1 Buffer allocation problem	218
8.2 An approximation algorithm for open networks with blocking	220
8.3 Dynamic programming approach	222
8.3.1 Forward problem	222
8.3.2 Backward problem	224
8.3.3 Algorithm	225
8.4 An extension	225
8.4.1 Forward problem	227
8.4.2 Backward problem	227
8.4.3 Algorithm	228
8.5 Validation	229
8.6 Bibliographical notes	232
References	233
References	235
Table of Symbols	249
Index	251