# Contents

Biography xi
Preface xiii
Acknowledgments xvii
List of Abbreviations xix
List of Symbols xxvii

## 1 Introduction

1.1 Cellular Mobile Communication Systems 1
   1.1.1 The Cellular Concept 2
   1.1.2 Propagation Impairments in Cellular Systems 3
   1.1.3 Multiple-Access Schemes 3
   1.1.4 First- and Second-Generation Systems 4
   1.1.5 Third-Generation Systems 5
   1.1.6 Towards Fourth-Generation Systems 7

1.2 Networks and Protocols 8
   1.2.1 Circuit-Switched and Packet-Switched Networks 9
   1.2.2 Internet Protocol Suite 10
   1.2.3 Routing in Internetworks 11

1.3 Multipoint Communications 12
   1.3.1 Unicast 12
   1.3.2 Broadcast 13
   1.3.3 Multicast 13

1.4 IP Multicast 14
   1.4.1 Multicast Groups 14
   1.4.2 Multicast Routing 15

1.5 Multicast in Cellular Mobile Networks 16
   1.5.1 Cell Broadcast Service 16
   1.5.2 IP Multicast 17
4 Multicast Services for Third-Generation Networks 67
4.1 Introduction 67
4.2 Motivation for Multicast 69
  4.2.1 Revenue Growth 69
  4.2.2 Differentiation 70
  4.2.3 Cost of Service Delivery 70
4.3 Multicast Services 70
  4.3.1 Mobile TV 71
  4.3.2 Multimedia Content Distribution 72
  4.3.3 General Content Distribution 74
  4.3.4 Enhanced Distribution Services 75
  4.3.5 Peer-to-Peer Communication 76
  4.3.6 Machine-to-Machine Distribution 77
4.4 User Requirements and Technology Acceptance 78
  4.4.1 Requirement Analysis 79
  4.4.2 Technology Adoption Cycles 81
  4.4.3 User Acceptance of Mobile Services 83
4.5 Summary 85

5 Multicast Extensions for Third-Generation Networks 87
5.1 Introduction 87
5.2 MBMS for UMTS 87
  5.2.1 Overview of MBMS Architecture 88
  5.2.2 Core Network Extensions 89
  5.2.3 Radio Access Network Extensions 91
  5.2.4 Multicast Service Provisioning Phases 93
  5.2.5 Broadcast Service Provisioning Phases 97
5.3 BCMCS for CDMA2000 99
  5.3.1 Overview of BCMCS Architecture 99
  5.3.2 Core Network Extensions 101
  5.3.3 Radio Access Network Extensions 102
  5.3.4 Service Provisioning Phases 105
5.4 Summary 107

6 Protocols and Mechanisms for MBMS 109
6.1 Introduction 109
6.2 MBMS Bearer Service Basics 111
  6.2.1 MBMS Bearer Service Architecture 111
  6.2.2 MBMS Bearer Context 113
  6.2.3 MBMS UE Context 114
6.3 MBMS Bearer Service Management 115
  6.3.1 MBMS Activation and Deactivation 116
  6.3.2 MBMS Registration and Deregistration 119
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3.3</td>
<td>MBMS Session Control</td>
<td>123</td>
</tr>
<tr>
<td>6.3.4</td>
<td>MBMS Service Request</td>
<td>127</td>
</tr>
<tr>
<td>6.4</td>
<td>Routing on the MBMS Bearer Path</td>
<td>128</td>
</tr>
<tr>
<td>6.5</td>
<td>MBMS User Services</td>
<td>130</td>
</tr>
<tr>
<td>6.5.1</td>
<td>MBMS Streaming Delivery Method</td>
<td>131</td>
</tr>
<tr>
<td>6.5.2</td>
<td>MBMS Download Delivery Method</td>
<td>133</td>
</tr>
<tr>
<td>6.5.3</td>
<td>MBMS User Service Announcement and Discovery</td>
<td>134</td>
</tr>
<tr>
<td>6.5.4</td>
<td>File Repair Procedure</td>
<td>135</td>
</tr>
<tr>
<td>6.5.5</td>
<td>Reception Reporting Procedure</td>
<td>135</td>
</tr>
<tr>
<td>6.5.6</td>
<td>MBMS Security</td>
<td>136</td>
</tr>
<tr>
<td>6.6</td>
<td>Summary</td>
<td>138</td>
</tr>
<tr>
<td>7</td>
<td>Protocols and Mechanisms for BCMCS</td>
<td>139</td>
</tr>
<tr>
<td>7.1</td>
<td>Introduction</td>
<td>139</td>
</tr>
<tr>
<td>7.2</td>
<td>BCMCS Bearer Path Architecture</td>
<td>140</td>
</tr>
<tr>
<td>7.3</td>
<td>BCMCS Bearer Service Management</td>
<td>142</td>
</tr>
<tr>
<td>7.3.1</td>
<td>BCMCS Registration and RAN Session Discovery</td>
<td>142</td>
</tr>
<tr>
<td>7.3.2</td>
<td>BCMCS Session Information Update</td>
<td>143</td>
</tr>
<tr>
<td>7.3.3</td>
<td>BCMCS Bearer Set-Up</td>
<td>144</td>
</tr>
<tr>
<td>7.3.4</td>
<td>BCMCS Bearer Release</td>
<td>145</td>
</tr>
<tr>
<td>7.4</td>
<td>BCMSC Service Layer</td>
<td>148</td>
</tr>
<tr>
<td>7.4.1</td>
<td>BCMCS Information Acquisition</td>
<td>149</td>
</tr>
<tr>
<td>7.4.2</td>
<td>BCMCS Flow Management</td>
<td>150</td>
</tr>
<tr>
<td>7.4.3</td>
<td>BCMCS Security</td>
<td>152</td>
</tr>
<tr>
<td>7.5</td>
<td>Summary</td>
<td>153</td>
</tr>
<tr>
<td>8</td>
<td>Multicast Capacity over the CDMA Air Interface</td>
<td>155</td>
</tr>
<tr>
<td>8.1</td>
<td>Introduction</td>
<td>155</td>
</tr>
<tr>
<td>8.2</td>
<td>PTP and PTM Channels for Multicast</td>
<td>156</td>
</tr>
<tr>
<td>8.2.1</td>
<td>Power Control</td>
<td>156</td>
</tr>
<tr>
<td>8.2.2</td>
<td>Soft and Hard Handover</td>
<td>157</td>
</tr>
<tr>
<td>8.3</td>
<td>System Model</td>
<td>157</td>
</tr>
<tr>
<td>8.3.1</td>
<td>Propagation Model</td>
<td>158</td>
</tr>
<tr>
<td>8.3.2</td>
<td>Interference Model</td>
<td>158</td>
</tr>
<tr>
<td>8.4</td>
<td>Analysis of Multicast Capacity</td>
<td>159</td>
</tr>
<tr>
<td>8.4.1</td>
<td>Multicast Capacity with PTP Channels</td>
<td>161</td>
</tr>
<tr>
<td>8.4.2</td>
<td>Multicast Capacity with PTM Channels</td>
<td>162</td>
</tr>
<tr>
<td>8.5</td>
<td>Numerical Results</td>
<td>163</td>
</tr>
<tr>
<td>8.5.1</td>
<td>Comparative Analysis</td>
<td>164</td>
</tr>
<tr>
<td>8.5.2</td>
<td>Sensitivity Analysis</td>
<td>167</td>
</tr>
<tr>
<td>8.6</td>
<td>Summary</td>
<td>172</td>
</tr>
<tr>
<td>9</td>
<td>Cost Analysis of Multicast Routing</td>
<td>175</td>
</tr>
<tr>
<td>9.1</td>
<td>Introduction</td>
<td>175</td>
</tr>
<tr>
<td>9.2</td>
<td>Dynamic Multicast for UMTS</td>
<td>176</td>
</tr>
</tbody>
</table>
9.2.1 Multicast Tables 177
9.2.2 Group Management 179
9.2.3 Multicast Mobility Management 180
9.2.4 Multicast Packet Forwarding 181
9.3 Cost Analysis 183
  9.3.1 Parameters for Cost Analysis 183
  9.3.2 Modelling of Multicast User Distribution 185
  9.3.3 Modelling of User Mobility 186
  9.3.4 Modelling of Packet Traffic 187
9.4 Numerical Results 187
  9.4.1 Packet Delivery Cost 189
  9.4.2 Location Update Cost 193
9.5 Summary 194

10 Parity-Based Reliable Multicast 197
10.1 Introduction 197
10.2 Loss Recovery for Reliable Multicast 197
  10.2.1 Mechanisms for Parity-Based Loss Recovery 198
  10.2.2 Reliable Multicast for MBMS 200
10.3 Performance Evaluation Method 201
  10.3.1 Performance Metrics 201
  10.3.2 Simulation Approach 203
  10.3.3 Packet Error Model 204
10.4 Reliable Multicast over the Air Interface 205
  10.4.1 PTP Channels for Multicast 206
  10.4.2 PTM Channels for Multicast 209
10.5 End-to-End Reliable Multicast 216
10.6 Summary 219

11 Mobile Multicast in Heterogeneous Networks 221
11.1 Introduction 221
11.2 Alternative Technologies for Mobile Multicast 222
  11.2.1 DVB-H 222
  11.2.2 MediaFLO 226
  11.2.3 Other Standards 227
11.3 Interworking and Convergence 228
11.4 Challenges for Multicast Delivery in Heterogeneous Networks 229
11.5 Multicast Delivery Coordination in Heterogeneous Networks 230
  11.5.1 Resource Management 231
  11.5.2 Group Management Support 232
  11.5.3 Service Example 234
11.6 Summary 236

Appendix A Derivation of Downlink Capacity 237
A.1 Ratio of Intercell Interference to Received Power 237