# Contents

**List of Contributors** xi  
**Foreword** xiii  
**Acknowledgments** xv  
**List of Abbreviations** xvii

1 **Introduction**
   *Esa Markus Metsälä and Juha T.T. Salmelin*
   1.1 To the Reader 1  
   1.2 Content 2  
   1.3 Scope 2  
   Reference 2

2 **LTE Backhaul**
   *Gerald Bedürftig, Jouko Kapanen, Esa Markus Metsälä and Juha T.T. Salmelin*
   2.1 Introduction 3  
   2.2 LTE Backhaul Planes 5  
   2.2.1 3GPP Planes and Protocol Stacks 5  
   2.2.2 Synchronization Plane 7  
   2.2.3 Management Plane 9  
   2.2.4 Active Monitoring Plane 9  
   2.2.5 Security Control Plane 10  
   2.2.6 Control and User Plane of Additional Proprietary Applications 10  
   2.3 Radio Features of LTE and LTE-A 11  
   2.3.1 LTE 11  
   2.3.2 LTE-A 12  
   2.4 Requirements for LTE Backhaul (SLAs) 17  
   2.4.1 Capacity 17  
   2.4.2 Latency and Loss 18  
   2.4.3 QoS Capabilities 21  
   2.4.4 Synchronization 21  
   2.4.5 Availability 22
3 Economic Modeling and Strategic Input for LTE Backhaul

Gabriel Waller and Esa Markus Metsälä

3.1 Introduction

3.1.1 Role of Backhaul Within LTE
3.1.2 Why and What to Model

3.2 Strategic Input for Planning

3.2.1 Physical Infrastructure
3.2.2 Transmission Media
3.2.3 Capacity and Interfaces
3.2.4 Network Technologies
3.2.5 Network Topology
3.2.6 Make or Buy
3.2.7 Backhaul Security Aspects

3.3 Quantifying Benefits

3.3.1 Revenue from LTE Backhaul
3.3.2 Contribution to Mobile Service Revenue
3.3.3 Cost Savings

3.4 Quantifying Costs

3.4.1 Equipment Purchases
3.4.2 Economic Lifetime
3.4.3 Operational Costs
3.4.4 Other Costs
4 Dimensioning Aspects and Analytical Models of LTE MBH Networks

Csaba Vulkán and Juha T.T. Salmelin

4.1 Introduction 73
4.2 Dimensioning Paradigm 76
4.3 Applications and QoE: Considerations 78
  4.3.1 Transmission Control Protocol 79
  4.3.2 Web Browsing 83
  4.3.3 Video Download 85
4.4 Dimensioning Requirements 87
4.5 Traffic Models 88
  4.5.1 Peak Load or Busy Hour Load 92
  4.5.2 Geographic Diversity and Daily Load Profile/Distribution 93
  4.5.3 Session Level User Behavior 95
  4.5.4 Burst Level User Behavior 99
  4.5.5 Packet Level Behavior 102
  4.5.6 Transmission Control Protocol Models 106
4.6 Network Models 112
  4.6.1 Queuing Methods 113
  4.6.2 Fluid Network Models 117
  4.6.3 Network Model 118
  4.6.4 Routing and Requirement Allocations 119
4.7 Dimensioning 122
  4.7.1 QoS-Driven Dimensioning 122
  4.7.2 Reliability Requirement Based Dimensioning 124
References 127

5 Planning and Optimizing Mobile Backhaul for LTE

Raija Lilius, Jari Salo, José Manuel Tapia Pérez and Esa Markus Metsälä

5.1 Introduction 129
  5.1.1 Planning and Optimization Process 130
  5.1.2 High-Level Design Overview 131
5.2 Backhaul Network Deployment Scenarios 132
  5.2.1 Connectivity Requirements 132
5.2.2 Differences Between Ethernet and IP Connectivity 133
5.2.3 Implications to Backhaul Scenarios 134
5.2.4 Ethernet Services 134
5.2.5 L3 VPN Service 136
5.2.6 Scenario 1: IP Access 137
5.2.7 Scenario 2: Ethernet Service in the Access 137

5.3 Network Topology and Transport Media 138
5.3.1 Access Network Topologies and Media 138
5.3.2 Aggregation Network Topologies 139

5.4 Availability and Resiliency Schemes 139
5.4.1 Availability Calculation 140
5.4.2 Link Resiliency and its Impact on Availability 141
5.4.3 Routing Gateway Redundancy 144
5.4.4 Ethernet Ring Protection (ERP) 147
5.4.5 IP and MPLS Rerouting 148
5.4.6 SCTP Multi-Homing 149
5.4.7 Connectivity Toward Multiple S-GWs and MMEs 149
5.4.8 Synchronization Protection 150
5.4.9 OSS Resiliency 150
5.4.10 End-to-End Performance of Multilayer Redundancy 151

5.5 QoS Planning 152
5.5.1 QoS in an Access Transport Node 152
5.5.2 Packet Classification 153
5.5.3 Scheduling 156
5.5.4 Traffic Shaping 158
5.5.5 Active Queue Management and Bufferbloat 160
5.5.6 Connection Admission Control 161

5.6 Link Bandwidth Dimensioning 163
5.6.1 Obtaining Input Parameters for User Plane Bandwidth Dimensioning 164
5.6.2 Obtaining Input Parameters for Control Plane Bandwidth Dimensioning 169
5.6.3 Link Bandwidth Dimensioning: Single Queue 172
5.6.4 Link Bandwidth Dimensioning: Multiple Queues 180
5.6.5 Combining Signaling, Voice and Data Traffic 183
5.6.6 Comparison of Bandwidth Dimensioning Formulas 186

5.7 Dimensioning Other Traffic Types 187
5.7.1 Management Traffic 187
5.7.2 Synchronization Traffic 187
5.7.3 Other Traffic Types 188

5.8 Base Station Site Solutions 188

5.9 Security Solutions 189
5.9.1 Network Element Hardening 190
5.9.2 Network Security High-Level Architecture 190
5.9.3 Security Gateway High Availability 192
5.9.4 IPsec Parameter Planning 196
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5.3</td>
<td>Configuring Network</td>
<td>265</td>
</tr>
<tr>
<td>7.5.4</td>
<td>Policy-Based Configuration Management</td>
<td>265</td>
</tr>
<tr>
<td>7.5.5</td>
<td>Planning Interfaces</td>
<td>266</td>
</tr>
<tr>
<td>7.5.6</td>
<td>Network Configuration Discovery</td>
<td>267</td>
</tr>
<tr>
<td>7.5.7</td>
<td>Configuration Management of Backhaul Network</td>
<td>267</td>
</tr>
<tr>
<td>7.6</td>
<td>Optimization</td>
<td>268</td>
</tr>
<tr>
<td>7.7</td>
<td>Self-Organizing Network (SON)</td>
<td>270</td>
</tr>
<tr>
<td>7.8</td>
<td>O&amp;M Protocols</td>
<td>272</td>
</tr>
<tr>
<td>7.8.1</td>
<td>SNMP</td>
<td>273</td>
</tr>
<tr>
<td>7.8.2</td>
<td>NETCONF</td>
<td>275</td>
</tr>
<tr>
<td>7.9</td>
<td>Planning of Network Management System</td>
<td>275</td>
</tr>
<tr>
<td>7.9.1</td>
<td>Strategic Planning</td>
<td>276</td>
</tr>
<tr>
<td>7.9.2</td>
<td>Analysis</td>
<td>276</td>
</tr>
<tr>
<td>7.9.3</td>
<td>Design</td>
<td>277</td>
</tr>
<tr>
<td>7.9.4</td>
<td>Implementation</td>
<td>278</td>
</tr>
<tr>
<td>7.9.5</td>
<td>Maintenance</td>
<td>278</td>
</tr>
<tr>
<td>References</td>
<td></td>
<td>278</td>
</tr>
</tbody>
</table>

8 Summary

Esa Markus Metsälä and Juha T.T. Salmelin

Index