The LTE/SAE Deployment Handbook

Edited by Jyrki T. J. Penttinen, Nokia Siemens Networks Innovation Center (NICE), Spain

Describing the essential aspects that need to be considered during the deployment and operational phases of 3GPP LTE/SAE networks, this book gives a complete picture of LTE systems, as well as providing many examples from operational networks. It demystifies the structure, functioning, planning and measurements of both the radio and core aspects of the evolved 3G system.

The content includes an overview of the LTE/SAE environment, architectural and functional descriptions of the radio and core network, functionality of the LTE applications, international roaming principles, security solutions and network measurement methods. In addition, this book gives essential guidelines and recommendations about the transition from earlier mobile communications systems towards the LTE/SAE era and the next generation of LTE, LTE-Advanced.

The book is especially suitable for the operators that face new challenges in the planning and deployment phases of LTE/SAE, and is also useful for network vendors, service providers, telecommunications consultancy companies and technical institutes as it provides practical information about the realities of the system.

Presented by WILEY
THE LTE/SAE DEPLOYMENT HANDBOOK
THE LTE/SAE DEPLOYMENT HANDBOOK

Edited by

Jyrki T. J. Penttinen
Nokia Siemens Networks Innovation Center (NICE), Spain
Contents

List of Contributors xv
Foreword xvii
Preface xix
Acknowledgments xxi
Glossary xxiii

1 General 1
   1.1 Introduction 1
   1.2 The LTE Scene 1
   1.3 The Role of LTE in Mobile Communications 2
   1.4 LTE/SAE Deployment Process 3
   1.5 The Contents of the Book 7
   References 9

2 Drivers for LTE/SAE 11
   2.1 Introduction 11
   2.2 Mobile System Generations 11
   2.3 Data Service Evolution 14
      2.3.1 Development up to 3G 14
      2.3.2 Demand for Multimedia 14
      2.3.3 Commercial LTE Deployments 17
      2.3.4 LTE Refarming Eases Development 17
   2.4 Reasons for the Deployment of LTE 19
      2.4.1 General 19
      2.4.2 Relationship with Alternative Models 19
      2.4.3 TD-LTE versus FD-LTE 20
   2.5 Next Steps of LTE/SAE 20
   2.6 Summary of the Benefits of LTE 21
   References 21

3 LTE/SAE Overview 23
   3.1 Introduction 23
   3.2 LTE/SAE Standards 24
   3.3 How to Find Information from Specs? 25
5.3 Interfaces
  5.3.1 Uu Interface 70
  5.3.2 X2 Interface 70
  5.3.3 S1 Interface 70
  5.3.4 S3 Interface 70
  5.3.5 S4 Interface 70
  5.3.6 S5 Interface 70
  5.3.7 S6a Interface 71
  5.3.8 S11 Interface 71
  5.3.9 SGi 71
  5.3.10 Gn/Gp 71
5.4 Protocol Stacks 71
  5.4.1 User Plane 71
  5.4.2 Control Plane 73
  5.4.3 Layer 1 73
  5.4.4 Layer 2 74
  5.4.5 Layer 3 75
5.5 Layer 2 Structure 75
References 77

6 Transport and Core Network 79
  6.1 Introduction 79
  6.2 Functionality of Transport Elements 79
    6.2.1 Transport Modules 79
    6.2.2 LTE Transport Protocol Stack 80
    6.2.3 Ethernet Transport 80
    6.2.4 IP Address Differentiation 81
    6.2.5 Traffic Prioritization on the IP Layer 81
    6.2.6 Traffic Prioritization on Ethernet Layer 81
    6.2.7 VLAN Based Traffic Differentiation 81
    6.2.8 IPsec 81
    6.2.9 Synchronization 82
    6.2.10 Timing Over Packet 82
    6.2.11 Synchronous Ethernet 83
  6.3 Transport Network 83
    6.3.1 Carrier Ethernet Transport 83
    6.3.2 Transport for S1-U Interface 84
  6.4 Core Network 85
  6.5 IP Multimedia Subsystem 86
    6.5.1 IMS Architecture 86
References 93

7 LTE Radio Network 95
  7.1 Introduction 95
  7.2 LTE Radio Interface 95
  7.3 LTE Spectrum 96
  7.4 OFDM and OFDMA 96
    7.4.1 General Principle 96
7.4.2 OFDM Transceiver Chain
7.4.3 Cyclic Prefix
7.4.4 Channel Estimation and Equalization
7.4.5 Modulation
7.4.6 Coding
7.4.7 Signal Processing Chain
7.5 SC-FDM and SC-FDMA
7.5.1 SC-FDM Transceiver Chain
7.5.2 PAPR Benefits
7.6 Reporting
7.6.1 CSI
7.6.2 CQI
7.6.3 RI
7.6.4 PMI
7.7 LTE Radio Resource Management
7.7.1 Introduction
7.7.2 QoS and Associated Parameters
7.8 RRM Principles and Algorithms Common to UL and DL
7.8.1 Connection Mobility Control
7.8.2 Admission Control
7.8.3 HARQ
7.8.4 Link Adaptation
7.8.5 Packet Scheduling
7.8.6 Load Balancing
7.9 Uplink RRM
7.9.1 Packet Scheduling: Specific UL Constraints
7.9.2 Link Adaptation
7.9.3 Uplink Signaling for Scheduling and Link Adaptation Support
7.10 Downlink RRM
7.10.1 Channel Quality, Feedback and Link Adaptation
7.10.2 Packet Scheduling
7.10.3 Inter Cell Interference Control
7.11 Intra-LTE Handover
References

8 Terminals and Applications
8.1 Introduction
8.2 Effect of Smartphones on LTE
8.2.1 General
8.2.2 Is LTE Capable Enough to Handle the Challenge?
8.2.3 LTE RRC States
8.3 Interworking
8.3.1 Simultaneous Support for LTE/SAE and 2G/3G
8.3.2 Support for CS Fallback and VoLTE
8.4 LTE Terminal Requirements
8.4.1 Performance
8.4.2 LTE-UE Categories
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.4.3 HW Architecture</td>
<td>144</td>
</tr>
<tr>
<td>8.4.4 Conformance Test Aspects</td>
<td>148</td>
</tr>
<tr>
<td>8.5 LTE Applications</td>
<td>149</td>
</tr>
<tr>
<td>8.5.1 Non-Operator Applications</td>
<td>149</td>
</tr>
<tr>
<td>8.5.2 Rich Communication Suite</td>
<td>151</td>
</tr>
<tr>
<td>8.5.3 LTE/SAE and RCS</td>
<td>154</td>
</tr>
<tr>
<td>References</td>
<td>155</td>
</tr>
<tr>
<td>9 Voice Over LTE</td>
<td>157</td>
</tr>
<tr>
<td>9.1 Introduction</td>
<td>157</td>
</tr>
<tr>
<td>9.2 CS Fallback for Evolved Packet System</td>
<td>158</td>
</tr>
<tr>
<td>9.3 SMS Over SGs</td>
<td>159</td>
</tr>
<tr>
<td>9.3.1 Functionality</td>
<td>160</td>
</tr>
<tr>
<td>9.3.2 Combined EPS/IMSI Attachment</td>
<td>160</td>
</tr>
<tr>
<td>9.3.3 Mobile Originated Short Message</td>
<td>161</td>
</tr>
<tr>
<td>9.3.4 Mobile Terminating Short Message</td>
<td>162</td>
</tr>
<tr>
<td>9.3.5 Deployment View</td>
<td>163</td>
</tr>
<tr>
<td>9.4 Voice and Other CS Services than SMS</td>
<td>164</td>
</tr>
<tr>
<td>9.4.1 Voice and Video Call</td>
<td>165</td>
</tr>
<tr>
<td>9.4.2 Call Unrelated to Supplementary and Location Services</td>
<td>166</td>
</tr>
<tr>
<td>9.4.3 Deployment View</td>
<td>169</td>
</tr>
<tr>
<td>9.5 Voice and SMS Over IP</td>
<td>169</td>
</tr>
<tr>
<td>9.5.1 IP Multimedia Subsystem</td>
<td>170</td>
</tr>
<tr>
<td>9.5.2 Voice and Video Telephony Over IP</td>
<td>171</td>
</tr>
<tr>
<td>9.6 Summary</td>
<td>186</td>
</tr>
<tr>
<td>References</td>
<td>187</td>
</tr>
<tr>
<td>10 Functionality of LTE/SAE</td>
<td>189</td>
</tr>
<tr>
<td>10.1 Introduction</td>
<td>189</td>
</tr>
<tr>
<td>10.2 States</td>
<td>189</td>
</tr>
<tr>
<td>10.2.1 Mobility Management</td>
<td>190</td>
</tr>
<tr>
<td>10.2.2 Handover</td>
<td>191</td>
</tr>
<tr>
<td>10.2.3 Connection Management</td>
<td>191</td>
</tr>
<tr>
<td>10.2.4 Authentication</td>
<td>196</td>
</tr>
<tr>
<td>10.2.5 Tracking Area</td>
<td>196</td>
</tr>
<tr>
<td>10.2.6 Paging Procedure</td>
<td>198</td>
</tr>
<tr>
<td>10.3 End-to-End Functionality</td>
<td>199</td>
</tr>
<tr>
<td>10.4 LTE/SAE Roaming</td>
<td>200</td>
</tr>
<tr>
<td>10.4.1 General</td>
<td>200</td>
</tr>
<tr>
<td>10.4.2 Roaming Architecture</td>
<td>201</td>
</tr>
<tr>
<td>10.4.3 Inter-Operator Connectivity</td>
<td>203</td>
</tr>
<tr>
<td>10.4.4 Home Routing</td>
<td>205</td>
</tr>
<tr>
<td>10.4.5 Local Breakout</td>
<td>206</td>
</tr>
<tr>
<td>10.4.6 Home Routing versus Local Breakout</td>
<td>208</td>
</tr>
<tr>
<td>10.4.7 Other Features</td>
<td>210</td>
</tr>
<tr>
<td>10.4.8 APN Usage</td>
<td>211</td>
</tr>
<tr>
<td>10.4.9 Service-Specific Aspects</td>
<td>212</td>
</tr>
</tbody>
</table>
10.5 Charging
  10.5.1 Offline Charging
  10.5.2 Charging Data Record
  10.5.3 Online Charging

References

11 LTE/SAE Security
  11.1 Introduction
  11.2 LTE Security Risk Identification
    11.2.1 Security Process
    11.2.2 Network Attack Types in LTE/SAE
    11.2.3 Preparation for Attacks
    11.2.4 Certificates
    11.2.5 LTE Transport Security
    11.2.6 Traffic Filtering
    11.2.7 Radio Interface Security
  11.3 LTE/SAE Service Security—Case Example
    11.3.1 General
    11.3.2 IPSec
    11.3.3 IPSec Processing and Security Gateway
    11.3.4 Single Tunnel with Dedicated Tunnel Interfaces
    11.3.5 Single Tunnel with Shared Tunnel Interfaces
    11.3.6 Multiple Tunnels with Dedicated Tunnel Interfaces
    11.3.7 Multiple Tunnels with Shared Tunnel Interfaces
    11.3.8 Summary
  11.4 Authentication and Authorization
  11.5 Customer Data Safety
  11.6 Lawful Interception

References

12 Planning and Deployment of SAE
  12.1 Introduction
  12.2 Network Evolution from 2G/3G PS Core to EPC
    12.2.1 3GPP R8 Requirements for LTE Support in Packet Core Network
    12.2.2 Introducing LTE in Operator Network
  12.3 Entering Commercial Phase: Support for Multi-Mode LTE/3G/2G Terminals with Pre-Release 8 SGSN
    12.3.1 Support for Multi-Mode LTE/3G/2G Terminals with Release 8 Network
    12.3.2 Optimal Solution for 2G/3G SGSN and MME from Architecture Point of View
  12.4 SGSN/MME Evolution
    12.4.1 Requirements to MME Functionality in LTE Networks
  12.5 Case Example: Commercial SGSN/MME Offering
    12.5.1 Nokia Siemens Networks Flexi Network Server
    12.5.2 Aspects to Consider in SGSN/MME Evolution Planning
12.6 Mobile Gateway Evolution 250
   12.6.1 Requirements to Mobile Gateway in Mobile Broadband Networks 250

12.7 Case Example: Commercial GGSN/S-GW/P-GW Offering 251
   12.7.1 Nokia Siemens Networks Flexi Network Gateway 251
   12.7.2 Aspects to Consider in GGSN/S-GW/P-GW Evolution Planning 252

12.8 EPC Network Deployment and Topology Considerations 252
   12.8.1 EPC Topology Options 252
   12.8.2 EPC Topology Evolution 253

12.9 LTE Access Dimensioning 254

13 Radio Network Planning 257
   13.1 Introduction 257
   13.2 Radio Network Planning Process 257
   13.3 Nominal Network Planning 260
      13.3.1 Quality of Service 261
   13.4 Capacity Planning 263
   13.5 Coverage Planning 264
      13.5.1 Radio Link Budget 265
      13.5.2 Radio Propagation Models 269
      13.5.3 Frequency Planning 270
      13.5.4 Other Planning Aspects 271
   13.6 Self-Optimizing Network 271

Reference 272

14 LTE/SAE Measurements 273
   14.1 Introduction 273
   14.2 General 273
      14.2.1 Measurement Points 273
   14.3 Principles of Radio Interface Measurements 273
      14.3.1 LTE Specific Issues for the Measurements 274
      14.3.2 LTE Traffic Simulators 276
      14.3.3 Typical LTE Measurements 278
      14.3.4 Type Approval Measurements 280
      14.3.5 Modulation Error Measurements 281
      14.3.6 LTE Performance Simulations 281
   14.4 LTE Field Measurements 282
      14.4.1 Typical Field Test Environment 283
      14.4.2 Test Network Setup 284
      14.4.3 Test Case Selection 288
      14.4.4 Items to Assure 289
   14.5 Evolution Changes the Rules of Testing 289
   14.6 General Test Requirements and Methods for the LTE Air Interface 292
      14.6.1 OFDM Radio Testing 292
      14.6.2 MIMO Testing 294
      14.6.3 LI Testing 296
14.6.4 L2/L3 Testing in LTE 297
14.6.5 UE Test Loop Modes 297

14.7 Test Requirements in SAE 298
14.7.1 Testing at the Network Service Level 299

14.8 Throughput Testing 300
14.8.1 End-to-End Network Innovation 301
14.8.2 Base Station Scheduler as Key Controller of Radio Resources 301
14.8.3 L1 Performance vs. L3/PDCP Throughput 302
14.8.4 OTA (Over The Air) Testing 304
14.8.5 Summary 305

14.9 Self-Organizing Network Techniques for Test and Measurement 306
14.9.1 SON Definition and Basic Principles 306
14.9.2 Technical Issues and Impact on Network Planning 307
14.9.3 Effects on Network Installation, Commissioning and Optimization Strategies 308
14.9.4 Conclusion 309

14.10 Field Testing 309
14.10.1 LTE Coverage and Power Quality Measurements 311
14.10.2 Guidelines for LTE Measurements 317

References 323

15 Recommendations 325
15.1 Introduction 325
15.2 Transition to LTE—Use Cases 326
15.2.1 Total Swap 326
15.2.2 Hot Spots 326

15.3 Spectrum Aspects 327
15.3.1 General View on Spectrum Allocation 327
15.3.2 Coexistence with GSM 335

15.4 Effect of the Advanced GSM Features on the Fluent LTE Deployment 343
15.4.1 Common BCCH 344
15.4.2 AMR Full and Half Rate 347
15.4.3 Single Antenna Interference Cancellation 349
15.4.4 Orthogonal Subchannel 350
15.4.5 Antenna Hopping 354
15.4.6 EGPRS2 and Downlink Dual Carrier 357
15.4.7 Dynamic Frequency and Channel Allocation 359
15.4.8 Signaling Improvements 364

15.5 Alternative Network Migration Path (Multi-Operator Case) 367
15.5.1 Introduction to Network Sharing Variants 368
15.5.2 MORAN and MOBSS 369
15.5.3 MOCN 371
15.5.4 National Roaming, Geographical Roaming and IMSI Based Handover 374

15.6 Hardware Migration Path 376
15.6.1 Colocated Antenna Systems 377
15.6.2 Colocation with Shared Multi-Radio Base Station 380
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.7</td>
<td>Mobile Backhaul—Towards “All-IP” Transport</td>
<td>381</td>
</tr>
<tr>
<td>15.7.1</td>
<td>Motivation to IP Evolution in Mobile Backhaul</td>
<td>381</td>
</tr>
<tr>
<td>15.7.2</td>
<td>Transport Aspects in Packet Backhaul</td>
<td>383</td>
</tr>
<tr>
<td>15.8</td>
<td>LTE Interworking with Legacy Networks for the Optimal Voice and Data Services</td>
<td>384</td>
</tr>
<tr>
<td>15.8.1</td>
<td>Intersystem Mobility Management for Data Services</td>
<td>385</td>
</tr>
<tr>
<td>15.8.2</td>
<td>CS Fallback</td>
<td>394</td>
</tr>
<tr>
<td>15.8.3</td>
<td>Idle Mode Signaling Reduction</td>
<td>404</td>
</tr>
<tr>
<td>References</td>
<td></td>
<td>405</td>
</tr>
</tbody>
</table>

Index | 407 |