

---

# Contents

---

<b>Preface</b> . . . . .	xiii
<b>List of Acronyms</b> . . . . .	xv
<b>Chapter 1. General Characteristics</b> . . . . .	1
1.1. Network architecture . . . . .	1
1.1.1. EPS network . . . . .	1
1.1.2. MBMS network . . . . .	8
1.1.3. LCS network . . . . .	11
1.2. Bearer types . . . . .	14
1.2.1. Bearer structure . . . . .	14
1.2.2. Quality of Service . . . . .	15
1.3. Radio interface . . . . .	17
1.3.1. Structure of the radio interface . . . . .	18
1.3.2. NAS protocol. . . . .	19
1.3.3. RRC protocol. . . . .	20
1.3.4. Data link layer . . . . .	21
1.3.5. Logical channels . . . . .	22
1.3.6. Transport channels. . . . .	23
1.3.7. Physical layer. . . . .	24
1.3.8. Physical signals . . . . .	26
1.3.9. Physical channels . . . . .	27
1.3.10. Mobile categories. . . . .	29
1.4. Network procedures . . . . .	30
1.4.1. Connection procedure . . . . .	30
1.4.2. Attachment procedure . . . . .	30
1.4.3. Restoration procedure of the default bearer . . . . .	36

---

1.4.4. Establishment procedure of a dedicated bearer . . . . .	39
1.4.5. Location update procedure . . . . .	41
1.4.6. Handover procedure . . . . .	43
1.4.7. Multicast bearer establishment procedure . . . . .	45
<b>Chapter 2. NAS Protocol . . . . .</b>	<b>49</b>
2.1. Attachment . . . . .	49
2.1.1. Procedure . . . . .	49
2.1.2. Message structure . . . . .	51
2.2. Session establishment . . . . .	55
2.2.1. Procedure . . . . .	55
2.2.2. Message structure . . . . .	57
<b>Chapter 3. RRC Protocol . . . . .</b>	<b>63</b>
3.1. System information . . . . .	63
3.1.1. MIB message . . . . .	64
3.1.2. SIB1 message . . . . .	64
3.1.3. SIB2 message . . . . .	66
3.1.4. SIB3 message . . . . .	67
3.1.5. SIB4 message . . . . .	68
3.1.6. SIB5 message . . . . .	68
3.1.7. SIB6 message . . . . .	68
3.1.8. SIB7 message . . . . .	69
3.1.9. SIB8 message . . . . .	69
3.1.10. SIB9 message . . . . .	70
3.1.11. SIB10 message . . . . .	70
3.1.12. SIB11 message . . . . .	71
3.1.13. SIB12 message . . . . .	71
3.1.14. SIB13 message . . . . .	72
3.2. Connection control . . . . .	72
3.2.1. Paging . . . . .	72
3.2.2. Connection establishment . . . . .	73
3.2.3. Security activation . . . . .	75
3.2.4. Connection reconfiguration . . . . .	76
3.2.5. Connection re-establishment . . . . .	78
3.2.6. Connection release . . . . .	79
3.3. Measurements . . . . .	80
3.3.1. Introduction . . . . .	80
3.3.2. Objects . . . . .	80
3.3.3. Events . . . . .	81
3.3.4. Measurement filtering . . . . .	85

---

3.3.5. Measurement report . . . . .	85
3.4. Broadcast control . . . . .	85
3.4.1. Configuration of frames and subframes . . . . .	85
3.4.2. MCCH logical channel scheduling . . . . .	86
3.4.3. MTCH logical channel scheduling . . . . .	87
3.4.4. Counting . . . . .	89
<b>Chapter 4. Data Link Layer . . . . .</b>	<b>91</b>
4.1. PDCP protocol . . . . .	91
4.1.1. Procedures . . . . .	92
4.1.2. Operations . . . . .	94
4.1.3. Protocol structure . . . . .	97
4.2. RLC protocol . . . . .	99
4.2.1. Operations . . . . .	100
4.2.2. Protocol structure . . . . .	102
4.3. MAC protocol . . . . .	107
4.3.1. Operations . . . . .	107
4.3.2. Protocol structure . . . . .	111
4.3.3. Control elements . . . . .	114
<b>Chapter 5. Physical Layer . . . . .</b>	<b>117</b>
5.1. Frequency plan . . . . .	117
5.1.1. Frequency bands . . . . .	117
5.1.2. Radio channel . . . . .	119
5.1.3. Aggregation of the radio channels . . . . .	121
5.1.4. Numbering of radio channels . . . . .	122
5.2. Multiplexing structure . . . . .	125
5.2.1. Time-division multiplexing . . . . .	125
5.2.2. Resource block . . . . .	130
5.2.3. Resource element group . . . . .	132
5.3. Transmission chain . . . . .	133
5.3.1. Error detection codes . . . . .	135
5.3.2. Error correction codes . . . . .	136
5.3.3. Modulation . . . . .	137
5.3.4. Antenna ports . . . . .	138
5.3.5. Transmission modes . . . . .	140
5.3.6. Inverse Fast Fourier Transform . . . . .	143
5.3.7. Configuration of the transmission . . . . .	144
5.3.8. Antenna configurations . . . . .	145

---

<b>Chapter 6. Downlink Physical Signals</b> . . . . .	149
6.1. PSS physical signal . . . . .	149
6.1.1. Sequence generation . . . . .	150
6.1.2. Mapping on the resource elements . . . . .	150
6.2. SSS physical signal . . . . .	152
6.2.1. Sequence generation . . . . .	152
6.2.2. Mapping on the resource elements . . . . .	153
6.3. Cell-Specific RS physical signal . . . . .	155
6.3.1. Sequence generation . . . . .	155
6.3.2. Mapping on the resource elements . . . . .	156
6.4. MBSFN RS physical signal. . . . .	159
6.4.1. Sequence generation . . . . .	159
6.4.2. Mapping on the resource elements . . . . .	160
6.5. UE-Specific RS physical signal . . . . .	162
6.5.1. Sequence generation . . . . .	162
6.5.2. Mapping on the resource elements . . . . .	164
6.6. PRS physical signal . . . . .	168
6.6.1. Sequence generation . . . . .	169
6.6.2. Mapping on the resource elements . . . . .	169
6.6.3. Configuration of the subframes . . . . .	170
6.7. CSI RS physical signal . . . . .	171
6.7.1. Sequence generation . . . . .	172
6.7.2. Mapping on the resource elements . . . . .	173
6.7.3. Configuration of the subframes . . . . .	174
<b>Chapter 7. Downlink Physical Channels</b> . . . . .	177
7.1. PBCH physical channel . . . . .	177
7.1.1. Error detection code . . . . .	178
7.1.2. Error correction code . . . . .	178
7.1.3. Rate matching . . . . .	178
7.1.4. Scrambling . . . . .	179
7.1.5. Modulation . . . . .	179
7.1.6. Mapping on the spatial layers . . . . .	179
7.1.7. Precoding . . . . .	180
7.1.8. Mapping on the resource elements . . . . .	181
7.2. PCFICH physical channel. . . . .	182
7.2.1. CFI information. . . . .	183
7.2.2. Error correction code . . . . .	183
7.2.3. Scrambling . . . . .	184
7.2.4. Modulation . . . . .	184
7.2.5. Mapping on the spatial layers . . . . .	184

---

7.2.6. Precoding . . . . .	185
7.2.7. Mapping on the resource elements . . . . .	186
7.3. PHICH physical channel . . . . .	188
7.3.1. HI information . . . . .	189
7.3.2. PHICH group . . . . .	189
7.3.3. Error correction code . . . . .	190
7.3.4. Modulation . . . . .	190
7.3.5. Scrambling and spreading . . . . .	191
7.3.6. Resource group alignment . . . . .	192
7.3.7. Mapping on the spatial layers . . . . .	193
7.3.8. Precoding . . . . .	193
7.3.9. Mapping on the resource elements . . . . .	195
7.3.10. Assignment of the PHICH physical channel . . . . .	199
7.4. PDCCH physical channel . . . . .	200
7.4.1. DCI information . . . . .	201
7.4.2. Error detection code . . . . .	207
7.4.3. Error correction code . . . . .	208
7.4.4. Rate matching . . . . .	208
7.4.5. Multiplexing . . . . .	209
7.4.6. Scrambling . . . . .	209
7.4.7. Modulation . . . . .	210
7.4.8. Mapping on the spatial layers . . . . .	210
7.4.9. Precoding . . . . .	211
7.4.10. Mapping on the resource elements . . . . .	212
7.4.11. Allocation of physical channel PDCCH . . . . .	215
7.5. PDSCH physical channel . . . . .	217
7.5.1. Error detection code . . . . .	218
7.5.2. Segmentation . . . . .	219
7.5.3. Error correction code . . . . .	219
7.5.4. Rate matching . . . . .	220
7.5.5. Concatenation . . . . .	221
7.5.6. Scrambling . . . . .	221
7.5.7. Modulation . . . . .	222
7.5.8. Mapping on the spatial layers . . . . .	222
7.5.9. Precoding . . . . .	224
7.5.10. Mapping on the resource elements . . . . .	225
7.5.11. Resource allocation . . . . .	227
7.6. PMCH physical channel . . . . .	235
7.6.1. Error detection codes . . . . .	236
7.6.2. Segmentation . . . . .	236
7.6.3. Error correction code . . . . .	236

7.6.4. Rate matching . . . . .	237
7.6.5. Concatenation . . . . .	237
7.6.6. Scrambling . . . . .	237
7.6.7. Modulation . . . . .	238
7.6.8. Mapping on the spatial layers . . . . .	238
7.6.9. Precoding . . . . .	238
7.6.10. Mapping on the resource elements. . . . .	238
<b>Chapter 8. Uplink Physical Signals . . . . .</b>	<b>241</b>
8.1. DM-RS physical channel . . . . .	241
8.1.1. DM-RS physical signal associated with PUSCH physical channel . . . . .	241
8.1.2. DM-RS physical signal associated with the PUCCH physical channel . . . . .	244
8.2. SRS physical signal . . . . .	246
8.2.1. Sequence generation . . . . .	247
8.2.2. Mapping on the resource elements . . . . .	248
8.2.3. Configuration of the subframes . . . . .	250
8.2.4. Transmission of the SRS physical signal . . . . .	252
8.2.5. Power control . . . . .	254
<b>Chapter 9. Uplink Physical Channels . . . . .</b>	<b>257</b>
9.1. PRACH physical channel . . . . .	257
9.1.1. Time structure of the preamble . . . . .	257
9.1.2. Frequency structure of the preamble . . . . .	260
9.1.3. Location of the preamble. . . . .	260
9.1.4. Sequence generation of the preamble . . . . .	264
9.1.5. Power control . . . . .	264
9.2. PUCCH physical channel . . . . .	265
9.2.1. UCI information . . . . .	266
9.2.2. Formats 1, 1a and 1b . . . . .	270
9.2.3. Formats 2, 2a and 2b . . . . .	273
9.2.4. Format 3 . . . . .	278
9.2.5. Configuration of the resource blocks . . . . .	281
9.2.6. Allocation of the PUCCH physical channel . . . . .	283
9.2.7. Power control . . . . .	284
9.3. PUSCH physical channel . . . . .	285
9.3.1. Error detection code . . . . .	287
9.3.2. Segmentation . . . . .	287
9.3.3. Error correction code . . . . .	288
9.3.4. Rate matching . . . . .	289

---

9.3.5. Concatenation . . . . .	289
9.3.6. Coding of the control data . . . . .	290
9.3.7. Multiplexing of the control and traffic data . . . . .	296
9.3.8. Interleaving . . . . .	296
9.3.9. Scrambling . . . . .	296
9.3.10. Modulation . . . . .	297
9.3.11. Mapping on the spatial layers . . . . .	297
9.3.12. Precoding . . . . .	299
9.3.13. Mapping on the resource elements . . . . .	300
9.3.14. Allocation of resources . . . . .	301
9.3.15. Frequency hopping . . . . .	303
9.3.16. Power control . . . . .	306
<b>Chapter 10. Radio Interface Procedures . . . . .</b>	<b>309</b>
10.1. Access control . . . . .	309
10.1.1. PRACH physical channel acquisition . . . . .	309
10.1.2. Random access . . . . .	311
10.2. Data transfer . . . . .	316
10.2.1. Scheduling . . . . .	316
10.2.2. DRX function . . . . .	319
10.2.3. SPS function . . . . .	320
10.2.4. HARQ function . . . . .	322
10.2.5. TTI bundling function . . . . .	329
<b>Bibliography . . . . .</b>	<b>331</b>
<b>Index . . . . .</b>	<b>335</b>