



# Contents

About the authors	xi
Preface	xiii
Acronyms	xvii
1. Open radio access network overview	1
The Open Radio Access Networks Alliance	1
On C-RAN, Open vRAN, OpenRAN, xRAN, and Telecommunications Infrastructure Project	7
Spectrum: enabling 5G	8
Traditional base station architectures	14
5G base station architectures	17
Functional splits	20
Coordinated Multipoint	28
A real-life example: enterprise 5G networking	34
Summary and conclusions	40
References	41
Further reading	41
2. System components, requirements, and interfaces	43
Next-Generation Radio Access Network overview and terminology	43
Central unit	48
Distributed unit	59
Radio unit	76

Distributed unit/radio unit interface, Enhanced Common Public Radio Interface protocol overview	86
Initial access	87
802.1CM	91
Fronthaul gateway	94
Cell site router/gateway	95
Form factor, environmental and power requirements	96
ASN.1	96
DiffServ	97
References	102
<b>3. Hardware system dimensioning</b>	<b>103</b>
Centralized/distributed unit use-case dimensioning for throughput	103
Use-case dimensioning for latency	108
Users/transmission time interval	110
eCPRI, fronthaul bandwidth and latency	112
Distributed unit internal IO	115
Memory dimensioning	117
HARQ process count dimensioning	126
Radio unit	127
References	137
Further reading	137
<b>4. Hardware architecture choices</b>	<b>139</b>
Scalability	139
Development cycle	141
Data center architecture	142
Cell site integrated (CU/DU) solutions	146
Radio unit	154
Integrated small cell	172

Multicore central processing unit selection criteria	174
PCIe performance	179
References	181
<b>5. System software</b>	<b>183</b>
Operating system	183
Networking stacks	197
Functional application platform interface	201
Security aspects	206
References	214
Further reading	214
<b>6. User-plane application components</b>	<b>215</b>
GTP Protocol	215
PDCP protocol	217
RLC Protocol	220
MAC protocol	222
eCPRI protocol overview	223
Low physical layer	228
Digital front-end	230
References	234
Further reading	235
<b>7. Wireless scheduling and Quality of Service optimization techniques</b>	<b>237</b>
Orthogonal frequency division multiple access	237
Base station scheduler algorithms	242
Architectural framework for the base station wireless scheduler algorithm	249
System-level optimization	254
Software optimization techniques	257

References	260
Further reading	262
<b>8. Synchronization in open radio access networks</b>	<b>265</b>
Understanding frequency, time, syntonization, and synchronization	265
How do we get time?	269
O-RAN synchronization	273
Cellular network synchronization requirements	290
Synchronization in O-RAN	292
O-RAN network-level synchronization	292
O-RAN sync equipment requirements	296
Sync solution implementation	298
The effects of timestamping location and resolution	303
Unraveling the standards spaghetti	305
Further reading	306
<b>9. Software performance</b>	<b>309</b>
Packet processing cycle budget analysis	310
Physical Layer complexity analysis	313
Central Processing Unit loading summary	319
System-on-Chip performance counters	319
Life-of-a-packet double data rate utilization analysis	320
Mitigation techniques: what if the product does not meet performance targets?	320
Development environment optimization	321
Software optimization techniques	322
Reference	327
<b>10. Interoperability and test</b>	<b>329</b>
Development testing	329
System test setup	332

Performance testing	340
Front-, mid-, and backhaul testing	345
Operator acceptance testing	345
Regulatory approval testing	346
References	347
<b>11. Differentiation by use case</b>	<b>349</b>
Ultra-reliable low-latency communication	349
Vehicle-to-infrastructure (vehicle-to-everything) roadside unit architecture and implementation	354
5G Reduced Capabilities (RedCap)	360
References	362
Further reading	363
<b>Index</b>	<b>365</b>