ISO/IES/IEEE 8802-11:2012-11 (E)

Information technology_- Telecommunications and information exchange between systems_- Local and metropolitan area networks_- Specific requirements_- Part_11: Wireless LAN medium access control_(MAC) and physical layer_(PHY) specifications

Contents

1. Overview ... 1

1.1 Scope ... 1
1.2 Purpose ... 1
1.3 Supplementary information on purpose ... 1
1.4 Word Usage ... 2

2. Normative references ... 2

3. Definitions, acronyms, and abbreviations ... 5

3.1 Definitions ... 5
3.2 Definitions specific to IEEE 802.11 ... 24
3.3 Abbreviations and acronyms ... 34

4. General description ... 44

4.1 General description of the architecture ... 44
4.2 How WLAN systems are different ... 44
4.2.1 Introduction ... 44
4.2.2 Wireless station (STA) ... 44
4.2.3 Media impact on design and performance ... 44
4.2.4 The impact of handling mobile STAs ... 45
4.2.5 Interaction with other IEEE 802® layers ... 45
4.2.6 Interaction with non-IEEE-802 protocols ... 45
4.3 Components of the IEEE 802.11 architecture ... 45
4.3.1 General ... 45
4.3.2 The independent BSS (IBSS) as an ad hoc network ... 46
4.3.3 STA membership in a BSS is dynamic ... 46
4.3.4 Distribution system (DS) concepts ... 46
4.3.4.1 Overview ... 46
4.3.4.2 Extended service set (ESS): The large coverage network ... 47
4.3.4.3 Robust security network association (RSNA) ... 48
4.3.5 Area concepts ... 49
4.3.6 Integration with wired LANs ... 50
4.3.7 QoS BSS: The QoS network ... 51
4.3.8 Wireless LAN Radio Measurements ... 52
4.3.8.1 General ... 52
4.3.8.2 Beacon ... 53
4.3.8.3 Measurement Pilot ... 53
4.3.8.4 Frame ... 53
4.3.8.5 Channel load ... 54
4.3.8.6 Noise histogram ... 54
4.3.8.7 STA statistics ... 54
4.3.8.8 Location ... 54
4.3.8.9 Measurement pause ... 54
4.3.8.10 Neighbor report ... 54
4.3.8.11 Link measurement ... 54
4.3.8.12 Transmit stream/category measurement ... 55
4.3.9 Operation in licensed frequency bands ... 55
4.3.9.1 General ... 55
4.3.9.2 Dynamic STA enablement (DSE) in licensed bands ... 55

4.3.9.3 Contention-Based Protocol (CBP) in nonexclusively licensed bands .. 55
4.3.9.4 Using DSE STA identification to resolve interference 55
4.3.9.5 Further coexistence enhancements in nonexclusively licensed bands .. 55
4.3.10 High-throughput (HT) STA 56
4.3.11 STA transmission of data frames outside the context of a BSS 56
4.3.12 Tunneled direct-link setup 57
4.3.13 Wireless network management 57
4.3.13.1 Overview 57
4.3.13.2 BSS Max idle period management 58
4.3.13.3 BSS transition management 58
4.3.13.4 Channel usage 58
4.3.13.5 Collocated interference reporting 58
4.3.13.6 Diagnostic reporting 58
4.3.13.7 Directed multicast service (DMS) 58
4.3.13.8 Event reporting 58
4.3.13.9 FMS 59
4.3.13.10 Location services 59
4.3.13.11 Multicast diagnostic reporting 59
4.3.13.12 Multiple BSSID capability 59
4.3.13.13 Proxy ARP 59
4.3.13.14 QoS traffic capability 59
4.3.13.15 SSID list 59
4.3.13.16 Triggered STA statistics 59
4.3.13.17 TIM broadcast 60
4.3.13.18 Timing measurement 60
4.3.13.19 Traffic filtering service 60
4.3.13.20 U-APSD Coexistence 60
4.3.13.21 WNM-Notification 60
4.3.13.22 WNM-Sleep mode 60
4.3.14 Subscription service provider network (SSPN) interface 60
4.3.15 Mesh BSS: IEEE 802.11 wireless mesh network 61
4.3.15.1 General 61
4.3.15.2 Overview of the mesh BSS 61
4.3.15.3 Mesh STA 62
4.3.15.4 IEEE 802.11 components and mesh BSS 62
4.3.15.5 Introduction to mesh functions 64
4.4 Logical service interfaces 67
4.4.1 General 67
4.4.2 SS 68
4.4.3 DSS 68
4.5 Overview of the services 69
4.5.1 General 69
4.5.2 Distribution of messages within a DS 70
4.5.2.1 Distribution 70
4.5.2.2 Integration 70
4.5.2.3 QoS traffic scheduling 71
4.5.3 Services that support the distribution service 71
4.5.3.1 General 71
4.5.3.2 Mobility types 71
4.5.3.3 Association 71
4.5.3.4 Reassociation 72
4.5.3.5 Disassociation 72
4.5.4 Access control and data confidentiality services 73
4.5.4.1 General 73

4.5.4.2 Authentication ... 73
4.5.4.3 Deauthentication ... 74
4.5.4.4 Data confidentiality ... 75
4.5.4.5 Key management ... 75
4.5.4.6 Data origin authenticity ... 75
4.5.4.7 Replay detection ... 76
4.5.4.8 Fast BSS transition ... 76
4.5.4.9 Robust management frame protection ... 76
4.5.5 Spectrum management services ... 76
4.5.5.1 General ... 76
4.5.5.2 TPC ... 76
4.5.5.3 DFS ... 77
4.5.6 Traffic differentiation and QoS support ... 77
4.5.7 Support for higher layer timer synchronization ... 77
4.5.8 Radio Measurement service ... 78
4.5.9 Interworking with external networks ... 78
4.6 Multiple logical address spaces ... 79
4.7 Differences between ESS and IBSS LANs ... 79
4.8 Differences between ESS and MBSS LANs ... 81
4.9 Reference model ... 81
4.9.1 General ... 81
4.9.2 Interworking reference model ... 82
4.10 IEEE Std 802.11 and IEEE Std 802.1X-2004 ... 83
4.10.1 General ... 83
4.10.2 IEEE 802.11 usage of IEEE Std 802.1X-2004 ... 83
4.10.3 Infrastructure functional model overview ... 84
4.10.3.1 General ... 84
4.10.3.2 AKM operations with AS ... 84
4.10.3.3 AKM Operations with a Password or PSK ... 86
4.10.3.4 Alternate operations with PSK ... 87
4.10.3.5 Disassociation ... 88
4.10.4 IBSS functional model description ... 88
4.10.4.1 General ... 88
4.10.4.2 Key usage ... 88
4.10.4.3 Sample IBSS 4-Way Handshakes ... 88
4.10.4.4 IBSS IEEE 802.1X example ... 90
4.10.5 Authenticator-to-AS protocol ... 90
4.10.6 PMKSA caching ... 91
4.10.7 Protection of group addressed robust management frames ... 91
4.11 Generic advertisement service (GAS) ... 91

5. MAC service definition ... 92

5.1 Overview of MAC services ... 92
5.1.1 Data service ... 92
5.1.1.1 General ... 92
5.1.1.2 Determination of UP ... 92
5.1.1.3 Determination of UP of received frames at the AP sent by other STAs in the BSS ... 92
5.1.1.4 Interpretation of priority parameter in MAC service primitives ... 93
5.1.1.5 Interpretation of service class parameter in MAC service primitives in a STA ... 93
5.1.2 Security services ... 94
5.1.3 MSDU ordering ... 95

5.1.4 MSDU format 95
5.1.5 MAC data service architecture 95
5.2 MAC data service specification 97
5.2.1 General 97
5.2.2 MA-UNITDATA.request 97
5.2.2.1 Function 97
5.2.2.2 Semantics of the service primitive 97
5.2.2.3 When generated 97
5.2.2.4 Effect of receipt 98
5.2.3 MA-UNITDATA.indication 99
5.2.3.1 Function 99
5.2.3.2 Semantics of the service primitive 99
5.2.3.3 When generated 100
5.2.3.4 Effect of receipt 100
5.2.4 MA-UNITDATA-STATUS.indication 101
5.2.4.1 Function 101
5.2.4.2 Semantics of the service primitive 102
5.2.4.3 When generated 103
5.2.4.4 Effect of receipt 103

6. Layer management 104

6.1 Overview of management model 104
6.2 Generic management primitives 105
6.3 MLME SAP interface 105
6.3.1 Introduction 105
6.3.2 Power management 106
6.3.2.1 Introduction 106
6.3.2.2 MLME-POWERMGT.request 106
6.3.2.3 MLME-POWERMGT.confirm 106
6.3.3 Scan 107
6.3.3.1 Introduction 107
6.3.3.2 MLME-SCAN.request 107
6.3.3.3 MLME-SCAN.confirm 109
6.3.4 Synchronization 115
6.3.4.1 Introduction 115
6.3.4.2 MLME-JOIN.request 115
6.3.4.3 MLME-JOIN.confirm 117
6.3.5 Authenticate 117
6.3.5.1 Introduction 117
6.3.5.2 MLME-AUTHENTICATE.request 117
6.3.5.3 MLME-AUTHENTICATE.confirm 118
6.3.5.4 MLME-AUTHENTICATE.indication 119
6.3.5.5 MLME-AUTHENTICATE.response 120
6.3.6 Deauthenticate 121
6.3.6.1 Introduction 121
6.3.6.2 MLME-DEAUTHENTICATE.request 121
6.3.6.3 MLME-DEAUTHENTICATE.confirm 122
6.3.6.4 MLME-DEAUTHENTICATE.indication 123
6.3.7 Associate 123
6.3.7.1 Introduction 123
6.3.7.2 MLME-ASSOCIATE.request 123
6.3.7.3 MLME-ASSOCIATE.confirm 125
6.3.7.4 MLME-ASSOCIATE.indication 128

6.3.7.5 MLME-ASSOCIATE.response 130
6.3.8 Reassociate 133
6.3.8.1 Introduction 133
6.3.8.2 MLME-REASSOCIATE.request 133
6.3.8.3 MLME-REASSOCIATE.confirm 135
6.3.8.4 MLME-REASSOCIATE.indication 138
6.3.8.5 MLME-REASSOCIATE.response 141
6.3.9 Disassociate 144
6.3.9.1 MLME-DISASSOCIATE.request 144
6.3.9.2 MLME-DISASSOCIATE.confirm 145
6.3.9.3 MLME-DISASSOCIATE.indication 146
6.3.10 Reset 146
6.3.10.1 Introduction 146
6.3.10.2 MLME-RESET.request 146
6.3.11 Start 147
6.3.11.1 Introduction 147
6.3.11.2 MLME-START.request 147
6.3.11.3 MLME-START.confirm 151
6.3.12 Stop 152
6.3.12.1 General 152
6.3.12.2 MLME-STOP.request 152
6.3.13 Protocol layer model for spectrum management and radio measurement 153
6.3.14 Measurement request 156
6.3.14.1 Introduction 156
6.3.14.2 MLME-MREQUEST.request 156
6.3.14.3 MLME-MREQUEST.indication 157
6.3.15 Channel measurement 158
6.3.15.1 Introduction 158
6.3.15.2 MLME-MEASURE.request 158
6.3.15.3 MLME-MEASURE.confirm 158
6.3.16 Measurement report 159
6.3.16.1 Introduction 159
6.3.16.2 MLME-MREPORT.request 159
6.3.16.3 MLME-MREPORT.indication 160
6.3.17 Channel switch 161
6.3.17.1 MLME-CHANNELSWITCH.request 161
6.3.17.2 MLME-CHANNELSWITCH.confirm 162
6.3.17.3 MLME-CHANNELSWITCH.indication 163
6.3.17.4 MLME-CHANNELSWITCH.response 164
6.3.18 TPC request 164
6.3.18.1 Introduction 164
6.3.18.2 MLME-TPCADAPT.request 165
6.3.18.3 MLME-TPCADAPT.confirm 165
6.3.19 SetKeys 166
6.3.19.1 MLME-SETKEYS.request 166
6.3.20 DeleteKeys 167
6.3.20.1 MLME-DELETEKEYS.request 167
6.3.21 MIC (Michael) failure event 168
6.3.21.1 MLME-MICHAELMICFAILURE.indication 168
6.3.22 EAPOL 169
6.3.22.1 MLME-EAPOL.request 169
6.3.22.2 MLME-EAPOL.confirm 169
6.3.23 MLME-PeerKeySTART 170
6.3.23.1 MLME- PeerKeySTART.request 170

6.3.24 SetProtection ... 171
6.3.24.1 MLME-SETPROTECTION.request ... 171
6.3.25 MLME-PROTECTEDFRAMEDROPPED ... 172
6.3.25.1 MLME- PROTECTEDFRAMEDROPPED.indication ... 172
6.3.26 TS management interface ... 172
6.3.26.1 General ... 172
6.3.26.2 MLME-ADDTS.request ... 173
6.3.26.3 MLME-ADDTS.confirm ... 174
6.3.26.4 MLME-ADDTS.indication ... 176
6.3.26.5 MLME-ADDTS.response ... 177
6.3.26.6 MLME-DELTS.request ... 179
6.3.26.7 MLME-DELTS.indication ... 180
6.3.27 Management of direct links ... 181
6.3.27.1 Introduction ... 181
6.3.27.2 MLME-DLS.request ... 181
6.3.27.3 MLME-DLS.confirm ... 182
6.3.27.4 MLME-DLS.indication ... 183
6.3.27.5 MLME-DLSTeardown.request ... 184
6.3.27.6 MLME-DLSTeardown.indication ... 185
6.3.28 Higher layer synchronization support ... 186
6.3.28.1 Introduction ... 186
6.3.28.2 MLME-HL-SYNC.request ... 186
6.3.28.3 MLME-HL-SYNC.indication ... 186
6.3.29 Block Ack ... 187
6.3.29.1 General ... 187
6.3.29.2 MLME-ADDBA.request ... 187
6.3.29.3 MLME-ADDBA.confirm ... 188
6.3.29.4 MLME-ADDBA.indication ... 189
6.3.29.5 MLME-ADDBA.response ... 190
6.3.29.6 MLME-DELBA.request ... 191
6.3.29.7 MLME-DELBA.indication ... 192
6.3.30 Schedule element management ... 193
6.3.30.1 Introduction ... 193
6.3.30.2 MLME-SCHEDULE.request ... 193
6.3.30.3 MLME-SCHEDULE.indication ... 193
6.3.31 Vendor-specific action ... 194
6.3.31.1 Introduction ... 194
6.3.31.2 MLME-VSPECIFIC.request ... 194
6.3.31.3 MLME-VSPECIFIC.indication ... 195
6.3.32 Neighbor report request ... 196
6.3.32.1 General ... 196
6.3.32.2 MLME-NEIGHBORREPREQ.request ... 196
6.3.32.3 MLME-NEIGHBORREPREQ.indication ... 197
6.3.33 Neighbor report response ... 198
6.3.33.1 General ... 198
6.3.33.2 MLME-NEIGHBORREPRESP.request ... 198
6.3.33.3 MLME-NEIGHBORREPRESP.indication ... 199
6.3.34 Link Measure Request ... 199
6.3.34.1 General ... 199
6.3.34.2 MLME-LINKMEASURE.request ... 200
6.3.34.3 MLME-LINKMEASURE.confirm ... 200
6.3.35 MLME SAP interface for resource request ... 202
6.3.35.1 MLME-RESOURCE-REQUEST.request ... 202
6.3.35.2 MLME-RESOURCE-REQUEST.indication ... 202

6.3.35.3 MLME-RESOURCE-REQUEST.response 203
6.3.35.4 MLME-RESOURCE-REQUEST.confirm 204
6.3.35.5 MLME-RESOURCE-REQUEST-LOCAL.request 204
6.3.35.6 MLME-RESOURCE-REQUEST-LOCAL.confirm 205
6.3.36 MLME SAP interface for remote requests 206
6.3.36.1 MLME-REMOTE-REQUEST.request 206
6.3.36.2 MLME-REMOTE-REQUEST.indication 206
6.3.37 Extended channel switch announcement 207
6.3.37.1 General 207
6.3.37.2 MLME-EXTCHANNELSWITCH.request 207
6.3.37.3 MLME-EXTCHANNELSWITCH.confirm 208
6.3.37.4 MLME-EXTCHANNELSWITCH.indication 209
6.3.37.5 MLME-EXTCHANNELSWITCH.response 210
6.3.38 DSE power constraint announcement 210
6.3.38.1 General 210
6.3.38.2 MLME-DSETPC.request 211
6.3.38.3 MLME-DSETPC.confirm 211
6.3.38.4 MLME-DSETPC.indication 212
6.3.38.5 MLME-DSETPC.response 213
6.3.39 Enablement 214
6.3.39.1 General 214
6.3.39.2 MLME-ENABLEMENT.request 214
6.3.39.3 MLME-ENABLEMENT.confirm 215
6.3.39.4 MLME-ENABLEMENT.indication 216
6.3.39.5 MLME-ENABLEMENT.response 217
6.3.40 Deenablement 218
6.3.40.1 MLME-DEENABLEMENT.request 218
6.3.40.2 MLME-DEENABLEMENT.indication 219
6.3.41 SA Query support 220
6.3.41.1 MLME-SAQuery.request 220
6.3.41.2 MLME-SAQuery.confirm 220
6.3.41.3 MLME-SAQuery.indication 221
6.3.41.4 MLME-SAQuery.response 221
6.3.42 Get TSF timer 222
6.3.42.1 General 222
6.3.42.2 MLME-GETTSFTIME.request 222
6.3.42.2 MLME-GETTSFTIME.confirm 223
6.3.43 Timing Advertisement 223
6.3.43.1 General 223
6.3.43.2 MLME-TIMING_ADVERTISEMENT.request 223
6.3.43.3 MLME-TIMING_ADVERTISEMENT.indication 224
6.3.44 TDLS Discovery 226
6.3.44.1 General 226
6.3.44.2 MLME-TDLSDISCOVERY.request 226
6.3.44.3 MLME-TDLSDISCOVERY.confirm 226
6.3.44.4 MLME-TDLSDISCOVERY.indication 227
6.3.44.5 MLME-TDLSDISCOVERY.response 228
6.3.45 TDLS direct-link establishment 229
6.3.45.1 General 229
6.3.45.2 MLME-TDLSSETUPREQUEST.request 230
6.3.45.3 MLME-TDLSSETUPREQUEST.indication 230
6.3.45.4 MLME-TDLSSETUPRESPONSE.request 231
6.3.45.5 MLME-TDLSSETUPRESPONSE.indication 231
6.3.45.6 MLME-TDLSSETUPCONFIRM.request 232

6.3.45.7 MLME-TDLSSETUPCONFIRM.indication ... 232
6.3.45.8 MLME-TDLSPOTENTIALPEERSTA.request ... 233
6.3.45.9 MLME-TDLSPOTENTIALPEERSTA.confirm ... 234
6.3.46 TDLS direct-link teardown ... 235
6.3.46.1 General ... 235
6.3.46.2 MLME-TDLSTEARDOWN.request ... 235
6.3.46.3 MLME-TDLSTEARDOWN.indication ... 236
6.3.47 TDLS Peer U-APSD ... 237
6.3.47.1 General ... 237
6.3.47.2 MLME-TDLSPTI.request ... 237
6.3.47.3 MLME-TDLSPTI.confirm ... 238
6.3.47.4 MLME-TDLSPTI.indication ... 239
6.3.47.5 MLME-TDLSPTI.response ... 239
6.3.48 TDLS channel switching ... 240
6.3.48.1 General ... 240
6.3.48.2 MLME-TDLSCHANNELSWITCH.request ... 241
6.3.48.3 MLME-TDLSCHANNELSWITCH.confirm ... 241
6.3.48.4 MLME-TDLSCHANNELSWITCH.indication ... 242
6.3.48.5 MLME-TDLSCHANNELSWITCH.response ... 243
6.3.49 TDLS Peer PSM ... 244
6.3.49.1 General ... 244
6.3.49.2 MLME-TDLSPEERPSM.request ... 244
6.3.49.3 MLME-TDLSPEERPSM.confirm ... 245
6.3.49.4 MLME-TDLSPEERPSM.indication ... 246
6.3.49.5 MLME-TDLSPEERPSM.response ... 246
6.3.50 Event request ... 247
6.3.50.1 General ... 247
6.3.50.2 MLME-EVLREQUEST.request ... 248
6.3.50.3 MLME-EVLREQUEST.indication ... 248
6.3.51 Event report ... 249
6.3.51.1 General ... 249
6.3.51.2 MLME-EVLREPORT.request ... 249
6.3.51.3 MLME-EVLREPORT.indication ... 250
6.3.52 Event ... 250
6.3.52.1 General ... 250
6.3.52.2 MLME-EVLOG.request ... 250
6.3.52.3 MLME-EVLOG.confirm ... 251
6.3.53 Diagnostic request ... 252
6.3.53.1 General ... 252
6.3.53.2 MLME-DIAGREQUEST.request ... 252
6.3.53.3 MLME-DIAGREQUEST.indication ... 253
6.3.54 Diagnostic report ... 254
6.3.54.1 MLME-DIAGREPORT.request ... 254
6.3.54.2 MLME-DIAGREPORT.indication ... 254
6.3.55 Location Configuration request ... 255
6.3.55.1 General ... 255
6.3.55.2 MLME-LOCATIONCFG.request ... 256
6.3.55.3 MLME-LOCATIONCFG.confirm ... 256
6.3.55.4 MLME-LOCATIONCFG.indication ... 257
6.3.55.5 MLME-LOCATIONCFG.response ... 258
6.3.56 Location track notification ... 259
6.3.56.1 General ... 259
6.3.56.2 MLME-LOCATIONTRACKNOTIF.request ... 259
6.3.56.3 MLME-LOCATIONTRACKNOTIF.indication ... 260

6.3.57 Timing measurement 261
6.3.57.1 General 261
6.3.57.2 MLME-TIMINGMSMT.request 261
6.3.57.3 MLME-TIMINGMSMT.confirm 262
6.3.57.4 MLME-TIMINGMSMT.indication 263
6.3.58 BSS Transition Management 265
6.3.58.1 BSS Transition Management procedure 265
6.3.58.2 MLME-BTMQUERY.request 265
6.3.58.3 MLME-BTMQUERY.indication 266
6.3.58.4 MLME-BTM.request 267
6.3.58.5 MLME-BTM.indication 268
6.3.58.6 MLME-BTM.response 269
6.3.58.7 MLME-BTM.confirm 270
6.3.59 FMS setup 272
6.3.59.1 General 272
6.3.59.2 MLME-FMS.request 272
6.3.59.3 MLME-FMS.confirm 273
6.3.59.4 MLME-FMS.indication 273
6.3.59.5 MLME-FMS.response 274
6.3.60 Collocated Interference request 275
6.3.60.1 General 275
6.3.60.2 MLME-CLINTERFERENCEREQUEST.request 276
6.3.60.3 MLME-CLINTERFERENCEREQUEST.indication 276
6.3.61 Collocated Interference report 277
6.3.61.1 General 277
6.3.61.2 MLME-CLINTERFERENCEREPORT.request 277
6.3.61.3 MLME-CLINTERFERENCEREPORT.indication 278
6.3.62 TFS Setup 279
6.3.62.1 General 279
6.3.62.2 MLME-TFS.request 279
6.3.62.3 MLME-TFS.confirm 280
6.3.62.4 MLME-TFS.indication 281
6.3.62.5 MLME-TFS.response 281
6.3.63 Sleep Mode request 283
6.3.63.1 General 283
6.3.63.2 MLME-SLEEPMODE.request 283
6.3.63.3 MLME-SLEEPMODE.indication 284
6.3.63.4 MLME-SLEEPMODE.response 285
6.3.63.5 MLME-SLEEPMODE.confirm 286
6.3.64 TIM broadcast setup 287
6.3.64.1 General 287
6.3.64.2 MLME-TIMBROADCAST.request 287
6.3.64.3 MLME-TIMBROADCAST.confirm 288
6.3.64.4 MLME-TIMBROADCAST.indication 289
6.3.64.5 MLME-TIMBROADCAST.response 289
6.3.65 QoS Traffic Capability Update 290
6.3.65.1 MLME-QOSTRAFFICCAPUPDATE.request 290
6.3.65.2 MLME-QOSTRAFFICCAPUPDATE.indication 291
6.3.66 Channel Usage request 292
6.3.66.1 General 292
6.3.66.2 MLME-CHANNELUSAGE.request 292
6.3.66.3 MLME-CHANNELUSAGE.confirm 293
6.3.66.4 MLME-CHANNELUSAGE.indication 294
6.3.66.5 MLME-CHANNELUSAGE.response 295

6.3.67 DMS request and response procedure ... 296
6.3.67.1 General ... 296
6.3.67.2 MLME-DMS.request ... 297
6.3.67.3 MLME-DMS.confirm ... 297
6.3.67.4 MLME-DMS.indication ... 298
6.3.67.5 MLME-DMS.response ... 299
6.3.67.6 MLME-DMS-TERM.request ... 299
6.3.67.7 MLME-DMS-TERM.indication ... 300
6.3.68 Timing Measurement Request ... 301
6.3.68.1 General ... 301
6.3.68.2 MLME-TIMINGMSMTRQ.request ... 301
6.3.68.3 MLME-TIMINGMSMTRQ.indication ... 301
6.3.69 WNM-Notification request ... 302
6.3.69.1 General ... 302
6.3.69.2 MLME-WNMNOTIFICATIONREQUEST.request ... 302
6.3.69.3 MLME-WNMNOTIFICATIONREQUEST indication ... 303
6.3.70 WNM-Notification response ... 303
6.3.70.1 MLME-WNMNOTIFICATIONRESPONSE.request ... 303
6.3.70.2 MLME-WNMNOTIFICATIONRESPONSE.indication ... 304
6.3.71 Network discovery and selection support ... 305
6.3.71.1 General ... 305
6.3.71.2 MLME-GAS.request ... 305
6.3.71.3 MLME-GAS.confirm ... 306
6.3.71.4 MLME-GAS.indication ... 307
6.3.71.5 MLME-GAS.response ... 308
6.3.72 QoS Map Set element management ... 309
6.3.72.1 General ... 309
6.3.72.2 MLME-QoSMap.request ... 310
6.3.72.3 MLME-QoSMap.indication ... 310
6.3.73 Mesh peering management ... 311
6.3.73.1 Introduction ... 311
6.3.73.2 MLME-MESHPEERINGMANAGEMENT.request ... 311
6.3.73.3 MLME-MESHPEERINGMANAGEMENT.confirm ... 312
6.3.73.4 MLME-MESHPEERINGMANAGEMENT.indication ... 312
6.3.73.5 MLME-MESHPEERINGMANAGEMENT.response ... 313
6.3.74 Mesh power management ... 314
6.3.74.1 Introduction ... 314
6.3.74.2 MLME-MESHPOWERMGT.request ... 314
6.3.74.3 MLME-MESHPOWERMGT.confirm ... 314
6.3.75 Mesh neighbor offset synchronization ... 315
6.3.75.1 Introduction ... 315
6.3.75.2 MLME-MESHNEIGHBOROFFSETSYNCSTART.request ... 315
6.3.75.3 MLME-MESHNEIGHBOROFFSETSYNCSTART.confirm ... 315
6.3.75.4 MLME-MESHNEIGHBOROFFSETCALCULATE.request ... 316
6.3.75.5 MLME-MESHNEIGHBOROFFSETCALCULATE.confirm ... 317
6.3.75.6 MLME-MESHNEIGHBOROFFSETSYNCSTOP.request ... 317
6.3.75.7 MLME-MESHNEIGHBOROFFSETSYNCSTOP.confirm ... 318
6.3.76 Mesh TBTT adjustment ... 318
6.3.76.1 Introduction ... 318
6.3.76.2 MLME-MESHTBTTADJUSTMENT.request ... 318
6.3.76.3 MLME-MESHTBTTADJUSTMENT.confirm ... 319
6.3.76.4 MLME-MESHTBTTADJUSTMENT.indication ... 320
6.3.76.5 MLME-MESHTBTTADJUSTMENT.response ... 321

6.3.77 MCCA management interface 322
6.3.77.1 Introduction 322
6.3.77.2 MLME-ACTIVATEMCCA.request 322
6.3.77.3 MLME-MCCASETUP.request 323
6.3.77.4 MLME-MCCASETUP.confirm 323
6.3.77.5 MLME-MCCASETUP.indication 324
6.3.77.6 MLME-MCCASETUP.response 325
6.3.77.7 MLME-MCCAADVERTISEMENT.request 326
6.3.77.8 MLME-MCCAADVERTISEMENT.confirm 326
6.3.77.9 MLME-MCCAADVERTISEMENT.indication 327
6.3.77.10 MLME-MCCAADVERTISEMENT.response 328
6.3.77.11 MLME-MCCATEARDOWN.request 328
6.3.77.12 MLME-MCCATEARDOWN.indication 329
6.3.78 MBSS congestion control 330
6.3.78.1 Introduction 330
6.3.78.2 MLME-MBSSCONGESTIONCONTROL.request 330
6.3.78.3 MLME-MBSSCONGESTIONCONTROL.indication 330
6.3.79 MBSS proxy update 331
6.3.79.1 Introduction 331
6.3.79.2 MLME-MBSSPROXYUPDATE.request 331
6.3.79.3 MLME-MBSSPROXYUPDATE.confirm 332
6.3.79.4 MLME-MBSSPROXYUPDATE.indication 333
6.3.79.5 MLME-MBSSPROXYUPDATE.response 333
6.3.80 MBSS mesh gate announcement 334
6.3.80.1 Introduction 334
6.3.80.2 MLME-MBSSGATEANNOUNCEMENT.request 334
6.3.80.3 MLME-MBSSGATEANNOUNCEMENT.indication 335
6.3.81 Mesh link metric 336
6.3.81.1 Introduction 336
6.3.81.2 MLME-MESHLINKMETRICREAD.request 336
6.3.81.3 MLME-MESHLINKMETRICREAD.confirm 336
6.3.81.4 MLME-MESHLINKMETRICREPORT.request 337
6.3.81.5 MLME-MESHLINKMETRICREPORT.indication 338
6.3.82 HWMP mesh path selection 339
6.3.82.1 Introduction 339
6.3.82.2 MLME-HWMPMESHPATHSELECTION.request 339
6.3.82.3 MLME-HWMPMESHPATHSELECTION.indication 340
6.4 MAC state generic convergence function (MSGCF) 341
6.4.1 Overview of the convergence function 341
6.4.2 Overview of convergence function state machine 341
6.4.3 Convergence function state list 341
6.4.3.1 ESS_CONNECTED 341
6.4.3.2 ESS_DISCONNECTED 341
6.4.3.3 ESS_DISENGAGING 342
6.4.3.4 STANDBY 342
6.4.4 Convergence function state transitions 343
6.4.4.1 Transitions to ESS_CONNECTED 343
6.4.4.2 Transitions to ESS_ DISCONNECTED 343
6.4.4.3 Transitions to ESS_DISENGAGING 343
6.4.4.4 Transitions to STANDBY 343
6.4.5 Convergence function informational events 344
6.4.6 MAC state generic convergence SAP 344
6.4.7 ESS status reporting 344
6.4.7.1 MSGCF-ESS-Link-Up 344

6.4.7.2 MSGCF-ESS-Link-Down.indication 345
6.4.7.3 MSGCF-ESS-Link-Going-Down 346
6.4.7.4 MSGCF-ESS-Link-Event-Rollback.indication 348
6.4.7.5 MSGCF-ESS-Link-Detected.indication 348
6.4.7.6 MSGCF-ESS-Link-Scan.request 350
6.4.7.7 MSGCF-ESS-Link-Scan.confirm 350
6.4.8 Network configuration 351
6.4.8.1 MSGCF-ESS-Link-Capability.request 351
6.4.8.2 MSGCF-ESS-Link-Capability.confirm 352
6.4.8.3 MSGCF-Set-ESS-Link-Parameters.request 353
6.4.8.4 MSGCF-Set-ESS-Link-Parameters.confirm 355
6.4.8.5 MSGCF-Get-ESS-Link-Parameters.request 356
6.4.8.6 MSGCF-Get-ESS-Link-Parameters.confirm 356
6.4.9 Network events 357
6.4.9.1 MSGCF-ESS-Link-Threshold-Report.indication 357
6.4.10 Network command interface 358
6.4.10.1 MSGCF-ESS-Link-Command.request 358
6.4.11 MAC state SME SAP—mobility management 359
6.4.11.1 MSSME-ESS-Link-Down-Predicted.indication 359
6.5 PLME SAP interface 360
6.5.1 General 360
6.5.2 PLME-RESET.request 360
6.5.2.1 Function 360
6.5.2.2 Semantics of the service primitive 360
6.5.2.3 When generated 360
6.5.2.4 Effect of receipt 360
6.5.3 PLME-CHARACTERISTICS.request 360
6.5.3.1 Function 360
6.5.3.2 Semantics of the service primitive 360
6.5.3.3 When generated 360
6.5.3.4 Effect of receipt 360
6.5.4 PLME-CHARACTERISTICS.confirm 360
6.5.4.1 Function 360
6.5.4.2 Semantics of the service primitive 361
6.5.4.3 When generated 364
6.5.4.4 Effect of receipt 364
6.5.5 PLME-DSSSTESTMODE.request 364
6.5.5.1 Function 364
6.5.5.2 Semantics of the service primitive 364
6.5.5.3 When generated 365
6.5.5.4 Effect of receipt 365
6.5.6 PLME-DSSSTESTOUTPUT.request 365
6.5.6.1 Function 365
6.5.6.2 Semantics of the service primitive 365
6.5.6.3 When generated 366
6.5.6.4 Effect of receipt 366
6.5.7 PLME-TXTIME.request 366
6.5.7.1 Function 366
6.5.7.2 Semantics of the service primitive 366
6.5.7.3 When generated 366
6.5.7.4 Effect of receipt 366
6.5.8 PLME-TXTIME.confirm 367
6.5.8.1 Function 367
6.5.8.2 Semantics of the service primitive 367

6.5.8.3 When generated ... 367
6.5.8.4 Effect of receipt ... 367

7. PHY service specification ... 368

7.1 Scope ... 368
7.2 PHY functions ... 368
7.3 Detailed PHY service specifications ... 368
7.3.1 Scope and field of application ... 368
7.3.2 Overview of the service ... 368
7.3.3 Overview of interactions ... 368
7.3.4 Basic service and options ... 368
7.3.4.1 General ... 368
7.3.4.2 PHY-SAP peer-to-peer service primitives ... 369
7.3.4.3 PHY-SAP sublayer-to-sublayer service primitives ... 369
7.3.4.4 PHY-SAP service primitives parameters ... 369
7.3.4.5 Vector descriptions ... 370
7.3.5 PHY-SAP detailed service specification ... 371
7.3.5.1 Introduction ... 371
7.3.5.2 PHY-DATA.request ... 371
7.3.5.3 PHY-DATA.indication ... 371
7.3.5.4 PHY-DATA.confirm ... 372
7.3.5.5 PHY-TXSTART.request ... 372
7.3.5.6 PHY-TXSTART.confirm ... 373
7.3.5.7 PHY-TXEND.request ... 373
7.3.5.8 PHY-TXEND.confirm ... 374
7.3.5.9 PHY-CCARESET.request ... 374
7.3.5.10 PHY-CCARESET.confirm ... 375
7.3.5.11 PHY-CCA.indication ... 375
7.3.5.12 PHY-RXSTART.indication ... 376
7.3.5.13 PHY-RXEND.indication ... 377
7.3.5.14 PHY-CONFIG.request ... 378
7.3.5.15 PHY-CONFIG.confirm ... 378
7.4 PHY management ... 379

8. Frame formats ... 380

8.1 General requirements ... 380
8.2 MAC frame formats ... 380
8.2.1 Basic components ... 380
8.2.2 Conventions ... 380
8.2.3 General frame format ... 381
8.2.4 Frame fields ... 382
8.2.4.1 Frame Control field ... 382
8.2.4.2 Duration/ID field ... 386
8.2.4.3 Address fields ... 387
8.2.4.4 Sequence Control field ... 388
8.2.4.5 QoS Control field ... 389
8.2.4.6 HT Control field ... 394
8.2.4.7 Frame Body field ... 398
8.2.4.8 FCS field ... 400
8.2.5 Duration/ID field (QoS STA) ... 401
8.2.5.1 General ... 401

8.2.5.2 Setting for single and multiple protection under enhanced distributed channel access (EDCA) ... 401
8.2.5.3 Setting for QoS CF-Poll frames ... 402
8.2.5.4 Setting for frames sent by a TXOP holder under HCCA ... 402
8.2.5.5 Settings within a PSMP sequence ... 403
8.2.5.6 Settings within a dual CTS sequence ... 403
8.2.5.7 Setting for control response frames ... 403
8.2.5.8 Setting for other response frames ... 404
8.3 Format of individual frame types ... 404
8.3.1 Control frames ... 404
8.3.1.1 Format of control frames ... 404
8.3.1.2 RTS frame format ... 404
8.3.1.3 CTS frame format ... 405
8.3.1.4 ACK frame format ... 405
8.3.1.5 PS-Poll frame format ... 406
8.3.1.6 CF-End frame format ... 406
8.3.1.7 CF-End+CF-Ack frame format ... 407
8.3.1.8 BlockAckReq frame format ... 407
8.3.1.9 BlockAck frame format ... 410
8.3.1.10 Control Wrapper frame ... 413
8.3.2 Data frames ... 413
8.3.2.1 Data frame format ... 413
8.3.2.2 A-MSDU format ... 416
8.3.3 Management frames ... 417
8.3.3.1 Format of management frames ... 417
8.3.3.2 Beacon frame format ... 419
8.3.3.3 ATIM frame format ... 423
8.3.3.4 Disassociation frame format ... 423
8.3.3.5 Association Request frame format ... 423
8.3.3.6 Association Response frame format ... 425
8.3.3.7 Reassociation Request frame format ... 426
8.3.3.8 Reassociation Response frame format ... 428
8.3.3.9 Probe Request frame format ... 429
8.3.3.10 Probe Response frame format ... 430
8.3.3.11 Authentication frame format ... 434
8.3.3.12 Deauthentication ... 436
8.3.3.13 Action frame format ... 436
8.3.3.14 Action No Ack frame format ... 436
8.3.3.15 Timing Advertisement frame format ... 437
8.4 Management frame body components ... 437
8.4.1 Fields that are not information elements ... 437
8.4.1.1 Authentication Algorithm Number field ... 437
8.4.1.2 Authentication Transaction Sequence Number field ... 438
8.4.1.3 Beacon Interval field ... 438
8.4.1.4 Capability Information field ... 438
8.4.1.5 Current AP Address field ... 441
8.4.1.6 Listen Interval field ... 442
8.4.1.7 Reason Code field ... 442
8.4.1.8 AID field ... 445
8.4.1.9 Status Code field ... 445
8.4.1.10 Timestamp field ... 449
8.4.1.11 Action field ... 449
8.4.1.12 Dialog Token field ... 451
8.4.1.13 DLS Timeout Value field ... 451

8.4.1.14 Block Ack Parameter Set field ... 451
8.4.1.15 Block Ack Timeout Value field ... 452
8.4.1.16 DELBA Parameter Set field ... 452
8.4.1.17 QoS Info field ... 452
8.4.1.18 Measurement Pilot Interval field ... 454
8.4.1.19 Max Transmit Power field ... 454
8.4.1.20 Transmit Power Used field ... 454
8.4.1.21 Channel Width field ... 455
8.4.1.22 SM Power Control field ... 455
8.4.1.23 PCO Phase Control field ... 455
8.4.1.24 PSMP Parameter Set field ... 456
8.4.1.25 PSMP STA Info field ... 456
8.4.1.26 MIMO Control field ... 458
8.4.1.27 CSI Report field ... 459
8.4.1.28 Noncompressed Beamforming Report field ... 461
8.4.1.29 Compressed Beamforming Report field ... 463
8.4.1.30 Antenna Selection Indices field ... 466
8.4.1.31 Organization Identifier field ... 467
8.4.1.32 Rate Identification field ... 467
8.4.1.33 GAS Query Response Fragment ID field ... 468
8.4.1.34 Venue Info field ... 468
8.4.1.35 Target Channel ... 471
8.4.1.36 Operating Class ... 471
8.4.1.37 Send-Confirm field ... 472
8.4.1.38 Anti-Clogging Token field ... 472
8.4.1.39 Scalar field ... 472
8.4.1.40 Element field ... 472
8.4.1.41 Confirm field ... 473
8.4.1.42 Finite Cyclic Group field ... 473
8.4.2 Information elements ... 474
8.4.2.1 General ... 474
8.4.2.2 SSID element ... 478
8.4.2.3 Supported Rates element ... 478
8.4.2.4 FH Parameter Set element ... 479
8.4.2.5 DSSS Parameter Set element ... 480
8.4.2.6 CF Parameter Set element ... 480
8.4.2.7 TIM element ... 480
8.4.2.8 IBSS Parameter Set element ... 482
8.4.2.9 Challenge Text element ... 483
8.4.2.10 Country element ... 483
8.4.2.11 Hopping Pattern Parameters element ... 485
8.4.2.12 Hopping Pattern Table element ... 486
8.4.2.13 Request element ... 486
8.4.2.14 ERP element ... 487
8.4.2.15 Extended Supported Rates element ... 487
8.4.2.16 Power Constraint element ... 488
8.4.2.17 Power Capability element ... 488
8.4.2.18 TPC Request element ... 489
8.4.2.19 TPC Report element ... 489
8.4.2.20 Supported Channels element ... 490
8.4.2.21 Channel Switch Announcement element ... 490
8.4.2.22 Secondary Channel Offset element ... 491
8.4.2.23 Measurement Request element ... 492
8.4.2.24 Measurement Report element ... 519

8.4.2.25 Quiet element ... 553
8.4.2.26 IBSS DFS element ... 554
8.4.2.27 RSNE ... 555
8.4.2.28 Vendor Specific element ... 562
8.4.2.29 Extended Capabilities element ... 562
8.4.2.30 BSS Load element ... 566
8.4.2.31 EDCA Parameter Set element ... 567
8.4.2.32 TSPEC element ... 569
8.4.2.33 TCLAS element ... 573
8.4.2.34 TS Delay element ... 578
8.4.2.35 TCLAS Processing element ... 578
8.4.2.36 Schedule element ... 579
8.4.2.37 QoS Capability element ... 580
8.4.2.38 AP Channel Report element ... 580
8.4.2.39 Neighbor Report element ... 580
8.4.2.40 RCPI element ... 585
8.4.2.41 BSS Average Access Delay element ... 586
8.4.2.42 Antenna element ... 587
8.4.2.43 RSNI element ... 588
8.4.2.44 Measurement Pilot Transmission element ... 588
8.4.2.45 BSS Available Admission Capacity element ... 589
8.4.2.46 BSS AC Access Delay element ... 590
8.4.2.47 RM Enabled Capabilities element ... 592
8.4.2.48 Multiple BSSID element ... 594
8.4.2.49 Mobility Domain element (MDE) ... 596
8.4.2.50 Fast BSS Transition element (FTE) ... 596
8.4.2.51 Timeout Interval element (TIE) ... 599
8.4.2.52 RIC Data element (RDE) ... 599
8.4.2.53 RIC Descriptor element ... 600
8.4.2.54 DSE Registered Location element ... 600
8.4.2.55 Extended Channel Switch Announcement element ... 602
8.4.2.56 Supported Operating Classes element ... 603
8.4.2.57 Management MIC element ... 603
8.4.2.58 HT Capabilities element ... 604
8.4.2.59 HT Operation element ... 613
8.4.2.60 20/40 BSS Intolerant Channel Report element ... 617
8.4.2.61 Overlapping BSS Scan Parameters element ... 618
8.4.2.62 20/40 BSS Coexistence element ... 618
8.4.2.63 Time Advertisement element ... 619
8.4.2.64 Link Identifier element ... 621
8.4.2.65 Wakeup Schedule element ... 621
8.4.2.66 Channel Switch Timing element ... 622
8.4.2.67 PTI Control element ... 622
8.4.2.68 TPU Buffer Status element ... 623
8.4.2.69 Event Request element ... 624
8.4.2.70 Event Report element ... 630
8.4.2.71 Diagnostic Request element ... 636
8.4.2.72 Diagnostic Report element ... 647
8.4.2.73 Location Parameters element ... 649
8.4.2.74 Nontransmitted BSSID Capability element ... 657
8.4.2.75 SSID List element ... 657
8.4.2.76 Multiple BSSID-Index element ... 658
8.4.2.77 FMS Descriptor element ... 658
8.4.2.78 FMS Request element ... 659

8.4.2.79 FMS Response element ... 661
8.4.2.80 QoS Traffic Capability element ... 663
8.4.2.81 BSS Max Idle Period element ... 665
8.4.2.82 TFS Request element ... 665
8.4.2.83 TFS Response element ... 667
8.4.2.84 WNM-Sleep Mode element ... 668
8.4.2.85 TIM Broadcast Request element ... 670
8.4.2.86 TIM Broadcast Response element ... 670
8.4.2.87 Collocated Interference Report element ... 671
8.4.2.88 Channel Usage element ... 673
8.4.2.89 Time Zone element ... 674
8.4.2.90 DMS Request element ... 674
8.4.2.91 DMS Response element ... 676
8.4.2.92 Destination URI element ... 678
8.4.2.93 U-APSD Coexistence element ... 679
8.4.2.94 Interworking element ... 680
8.4.2.95 Advertisement Protocol element ... 681
8.4.2.96 Expedited Bandwidth Request element ... 683
8.4.2.97 QoS Map Set element ... 684
8.4.2.98 Roaming Consortium element ... 685
8.4.2.99 Emergency Alert Identifier element ... 686
8.4.2.100 Mesh Configuration element ... 686
8.4.2.101 Mesh ID element ... 690
8.4.2.102 Mesh Link Metric Report element ... 691
8.4.2.103 Congestion Notification element ... 691
8.4.2.104 Mesh Peering Management element ... 692
8.4.2.105 Mesh Channel Switch Parameters element ... 693
8.4.2.106 Mesh Awake Window element ... 694
8.4.2.107 Beacon Timing element ... 695
8.4.2.108 MCCAOP Setup Request element ... 696
8.4.2.109 MCCAOP Setup Reply element ... 697
8.4.2.110 MCCAOP Advertisement Overview element ... 698
8.4.2.111 MCCAOP Advertisement element ... 699
8.4.2.112 MCCAOP Teardown element ... 701
8.4.2.113 GANN element ... 701
8.4.2.114 RANN element ... 702
8.4.2.115 PREQ element ... 703
8.4.2.116 PREP element ... 705
8.4.2.117 PERR element ... 707
8.4.2.118 PXU element ... 708
8.4.2.119 PXUC element ... 709
8.4.2.120 Authenticated Mesh Peering Exchange element ... 710
8.4.2.121 MIC element ... 711
8.4.3 Information Subelements ... 711
8.4.4 Access Network Query Protocol (ANQP) elements ... 712
8.4.4.1 General ... 712
8.4.4.2 Query List ANQP-element ... 713
8.4.4.3 Capability List ANQP-element ... 713
8.4.4.4 Venue Name ANQP-element ... 714
8.4.4.5 Emergency Call Number ANQP-element ... 715
8.4.4.6 Network Authentication Type ANQP-element ... 715
8.4.4.7 Roaming Consortium ANQP-element ... 717
8.4.4.8 Vendor Specific ANQP-element ... 717
8.4.4.9 IP Address Type Availability ANQP-element ... 718

8.4.4.10 NAI Realm ANQP-element 719
8.4.4.11 3GPP Cellular Network ANQP-element 722
8.4.4.12 AP Geospatial Location ANQP-element 723
8.4.4.13 AP Civic Location ANQP-element 723
8.4.4.14 AP Location Public Identifier URI ANQP-element 723
8.4.4.15 Domain Name ANQP-element 724
8.4.4.16 Emergency Alert URI ANQP-element 724
8.4.4.17 Emergency NAI ANQP-element 725
8.4.4.18 TDLS Capability ANQP-element 725
8.4.4.19 Neighbor Report ANQP-element 726
8.5 Action frame format details 726
8.5.1 Introduction 726
8.5.2 Spectrum management Action frames 726
8.5.2.1 General 726
8.5.2.2 Measurement Request frame format 727
8.5.2.3 Measurement Report frame format 727
8.5.2.4 TPC Request frame format 728
8.5.2.5 TPC Report frame format 728
8.5.2.6 Channel Switch Announcement frame format 728
8.5.3 QoS Action frame details 729
8.5.3.1 General 729
8.5.3.2 ADDTS Request frame format 729
8.5.3.3 ADDTS Response frame format 730
8.5.3.4 DELTS frame format 731
8.5.3.5 Schedule frame format 732
8.5.3.6 QoS Map Configure frame format 732
8.5.4 DLS Action frame details 733
8.5.4.1 General 733
8.5.4.2 DLS Request frame format 733
8.5.4.3 DLS Response frame format 734
8.5.4.4 DLS Teardown frame format 735
8.5.5 Block Ack Action frame details 735
8.5.5.1 General 735
8.5.5.2 ADDBA Request frame format 736
8.5.5.3 ADDBA Response frame format 736
8.5.5.4 DELBA frame format 737
8.5.6 Vendor-specific action details 737
8.5.7 Radio Measurement action details 738
8.5.7.1 General 738
8.5.7.2 Radio Measurement Request frame format 738
8.5.7.3 Radio Measurement Report frame format 739
8.5.7.4 Link Measurement Request frame format 739
8.5.7.5 Link Measurement Report frame format 740
8.5.7.6 Neighbor Report Request frame format 742
8.5.7.7 Neighbor Report Response frame format 743
8.5.8 Public Action details 743
8.5.8.1 Public Action frames 743
8.5.8.2 20/40 BSS Coexistence Management frame format 744
8.5.8.3 Measurement Pilot frame format 744
8.5.8.4 DSE Enablement frame format 746
8.5.8.5 DSE Deenablement frame format 747
8.5.8.6 DSE Registered Location Announcement frame format 748
8.5.8.7 Extended Channel Switch Announcement frame format 748
8.5.8.8 DSE Measurement Request frame format 748

8.5.8.9 DSE Measurement Report frame format ... 749
8.5.8.10 DSE Power Constraint frame format ... 751
8.5.8.11 Vendor Specific Public Action frame format ... 752
8.5.8.12 GAS Initial Request frame format ... 752
8.5.8.13 GAS Initial Response frame format ... 753
8.5.8.14 GAS Comeback Request frame format ... 754
8.5.8.15 GAS Comeback Response frame format ... 755
8.5.8.16 TDLS Discovery Response frame format ... 756
8.5.8.17 Location Track Notification frame format ... 757
8.5.9 FT Action frame details ... 758
8.5.9.1 General ... 758
8.5.9.2 FT Request frame ... 758
8.5.9.3 FT Response frame ... 759
8.5.9.4 FT Confirm frame ... 760
8.5.9.5 FT Ack frame ... 761
8.5.10 SA Query Action frame details ... 761
8.5.10.1 General ... 761
8.5.10.2 SA Query Request frame ... 762
8.5.10.3 SA Query Response frame ... 762
8.5.11 Protected Dual of Public Action frames ... 763
8.5.12 HT Action frame details ... 763
8.5.12.1 HT Action field ... 763
8.5.12.2 Notify Channel Width frame format ... 764
8.5.12.3 SM Power Save frame format ... 764
8.5.12.4 PSMP frame format ... 765
8.5.12.5 Set PCO Phase frame format ... 765
8.5.12.6 CSI frame format ... 766
8.5.12.7 Noncompressed Beamforming frame format ... 766
8.5.12.8 Compressed Beamforming frame format ... 767
8.5.12.9 Antenna Selection Indices Feedback frame format ... 767
8.5.13 TDLS Action field formats ... 768
8.5.13.1 General ... 768
8.5.13.2 TDLS Setup Request Action field format ... 768
8.5.13.3 TDLS Setup Response Action field format ... 769
8.5.13.4 TDLS Setup Confirm Action field format ... 771
8.5.13.5 TDLS Teardown Action field format ... 772
8.5.13.6 TDLS Peer Traffic Indication Action field format ... 772
8.5.13.7 TDLS Channel Switch Request Action field format ... 773
8.5.13.8 TDLS Channel Switch Response Action field format ... 773
8.5.13.9 TDLS Peer PSM Request Action field format ... 774
8.5.13.10 TDLS Peer PSM Response Action field format ... 774
8.5.13.11 TDLS Peer Traffic Response Action field format ... 775
8.5.13.12 TDLS Discovery Request Action field format ... 775
8.5.14 WNM Action details ... 776
8.5.14.1 WNM Action fields ... 776
8.5.14.2 Event Request frame format ... 777
8.5.14.3 Event Report frame format ... 777
8.5.14.4 Diagnostic Request frame format ... 778
8.5.14.5 Diagnostic Report frame format ... 778
8.5.14.6 Location Configuration Request frame format ... 778
8.5.14.7 Location Configuration Response frame format ... 779
8.5.14.8 BSS Transition Management Query frame format ... 780
8.5.14.9 BSS Transition Management Request frame format ... 781
8.5.14.10 BSS Transition Management Response frame format ... 783

8.5.14.11 FMS Request frame format ... 784
8.5.14.12 FMS Response frame format ... 785
8.5.14.13 Collocated Interference Request frame format ... 785
8.5.14.14 Collocated Interference Report frame format ... 786
8.5.14.15 TFS Request frame format ... 787
8.5.14.16 TFS Response frame format ... 787
8.5.14.17 TFS Notify frame format ... 788
8.5.14.18 WNM-Sleep Mode Request frame format ... 788
8.5.14.19 WNM-Sleep Mode Response frame format ... 789
8.5.14.20 TIM Broadcast Request frame format ... 791
8.5.14.21 TIM Broadcast Response frame format ... 791
8.5.14.22 QoS Traffic Capability Update frame format ... 791
8.5.14.23 Channel Usage Request frame format ... 792
8.5.14.24 Channel Usage Response frame format ... 793
8.5.14.25 DMS Request frame format ... 793
8.5.14.26 DMS Response frame format ... 794
8.5.14.27 Timing Measurement Request frame format ... 794
8.5.14.28 WNM-Notification Request frame format ... 795
8.5.14.29 WNM-Notification Response frame format ... 796
8.5.15 Unprotected WNM Action details ... 797
8.5.15.1 Unprotected WNM Action fields ... 797
8.5.15.2 TIM frame format ... 797
8.5.15.3 Timing Measurement frame format ... 798
8.5.16 Self-protected Action frame details ... 799
8.5.16.1 Self-protected Action fields ... 799
8.5.16.2 Mesh Peering Open frame format ... 799
8.5.16.3 Mesh Peering Confirm frame format ... 801
8.5.16.4 Mesh Peering Close frame format ... 802
8.5.16.5 Mesh Group Key Inform frame format ... 803
8.5.16.6 Mesh Group Key Acknowledge frame format ... 804
8.5.17 Mesh Action frame details ... 804
8.5.17.1 Mesh Action fields ... 804
8.5.17.2 Mesh Link Metric Report frame format ... 805
8.5.17.3 HWMP Mesh Path Selection frame format ... 805
8.5.17.4 Gate Announcement frame format ... 806
8.5.17.5 Congestion Control Notification frame format ... 807
8.5.17.6 MCCA Setup Request frame format ... 807
8.5.17.7 MCCA Setup Reply frame format ... 807
8.5.17.8 MCCA Advertisement Request frame format ... 808
8.5.17.9 MCCA Advertisement frame format ... 808
8.5.17.10 MCCA Teardown frame format ... 809
8.5.17.11 TBTT Adjustment Request frame format ... 809
8.5.17.12 TBTT Adjustment Response frame format ... 810
8.5.18 Multihop Action frame details ... 811
8.5.18.1 Multihop Action fields ... 811
8.5.18.2 Proxy Update frame format ... 811
8.5.18.3 Proxy Update Confirmation frame format ... 811
8.6 Aggregate MPDU (A-MPDU) ... 812
8.6.1 A-MPDU format ... 812
8.6.2 MPDU delimiter CRC field ... 813
8.6.3 A-MPDU contents ... 814

9. MAC sublayer functional description 818

9.1 Introduction 818
9.2 MAC architecture 818
9.2.1 General 818
9.2.2 DCF 818
9.2.3 PCF 819
9.2.4 Hybrid coordination function (HCF) 819
9.2.4.1 General 819
9.2.4.2 HCF contention-based channel access (EDCA) 820
9.2.4.3 HCF controlled channel access (HCCA) 821
9.2.5 Mesh coordination function (MCF) 822
9.2.6 Combined use of DCF, PCF, and HCF 822
9.2.7 Fragmentation/defragmentation overview 822
9.2.8 MAC data service 823
9.3 DCF 824
9.3.1 General 824
9.3.2 Procedures common to the DCF and EDCAF 825
9.3.2.1 CS mechanism 825
9.3.2.2 MAC-Level Acknowledgements 825
9.3.2.3 IFS 826
9.3.2.4 Setting and resetting the NAV 828
9.3.2.5 RTS/CTS with fragmentation 829
9.3.2.6 CTS procedure 831
9.3.2.7 Dual CTS protection 831
9.3.2.8 ACK procedure 833
9.3.2.9 BlockAck procedure 834
9.3.2.10 Duplicate detection and recovery 834
9.3.2.11 NAV distribution 836
9.3.2.12 Operation of aSlotTime 836
9.3.3 Random backoff time 836
9.3.4 DCF access procedure 838
9.3.4.1 Introduction 838
9.3.4.2 Basic access 838
9.3.4.3 Backoff procedure for DCF 838
9.3.4.4 Recovery procedures and retransmit limits 840
9.3.4.5 Control of the channel 840
9.3.5 Individually addressed MPDU transfer procedure 842
9.3.6 Group addressed MPDU transfer procedure 842
9.3.7 DCF timing relations 843
9.3.8 Signal Extension 844
9.3.9 Determination of PLME aCWmin characteristics 844
9.4 PCF 844
9.4.1 General 844
9.4.2 CFP structure and timing 845
9.4.3 PCF access procedure 847
9.4.3.1 General 847
9.4.3.2 Fundamental access 847
9.4.3.3 NAV operation during the CFP 847
9.4.4 PCF transfer procedure 848
9.4.4.1 General 848
9.4.4.2 PCF transfers when the PC STA is transmitter or recipient 849
9.4.4.3 Operation with overlapping point-coordinated BSSs 850
9.4.4.4 CFPMaxDuration limit 850

9.4.4.5 CF usage rules ... 851
9.4.5 CF polling list ... 851
9.4.5.1 General ... 851
9.4.5.2 Polling list processing ... 852
9.4.5.3 Polling list update procedure ... 852
9.5 Fragmentation ... 852
9.6 Defragmentation ... 853
9.7 Multirate support ... 854
9.7.1 Overview ... 854
9.7.2 Basic MCS Set field ... 854
9.7.3 Basic STBC MCS ... 854
9.7.4 Basic Rate Set and Basic MCS Set for mesh STA ... 855
9.7.5 Rate selection for data and management frames ... 855
9.7.5.1 Rate selection for non-STBC Beacon and non-STBC PSMP frames ... 855
9.7.5.2 Rate selection for STBC group addressed data and management frames ... 855
9.7.5.3 Rate selection for other group addressed data and management frames ... 855
9.7.5.4 Rate selection for polling frames ... 856
9.7.5.5 Rate selection for +CF-Ack frames ... 856
9.7.5.6 Rate selection for other data and management frames ... 856
9.7.6 Rate selection for control frames ... 856
9.7.6.1 General rules for rate selection for control frames ... 856
9.7.6.2 Rate selection for control frames that initiate a TXOP ... 857
9.7.6.3 Rate selection for CF_End frames ... 858
9.7.6.4 Rate selection for control frames that are not control response frames ... 858
9.7.6.5 Rate selection for control response frames ... 859
9.7.6.6 Channel Width selection for control frames ... 862
9.7.6.7 Control frame TXVECTOR parameter restrictions ... 862
9.7.7 Multiple BSSID Rate Selection ... 862
9.7.8 Modulation classes ... 862
9.7.9 Non-HT basic rate calculation ... 863
9.8 MSDU transmission restrictions ... 864
9.9 HT Control field operation ... 865
9.10 Control Wrapper operation ... 865
9.11 A-MSDU operation ... 865
9.12 A-MPDU operation ... 866
9.12.1 A-MPDU contents ... 866
9.12.2 A-MPDU length limit rules ... 866
9.12.3 Minimum MPDU Start Spacing field ... 866
9.12.4 A-MPDU aggregation of group addressed data frames ... 867
9.12.5 Transport of A-MPDU by the PHY data service ... 867
9.13 PPDU duration constraint ... 867
9.14 LDPC operation ... 867
9.15 STBC operation ... 868
9.16 Short GI operation ... 868
9.17 Greenfield operation ... 868
9.18 Operation across regulatory domains ... 868
9.18.1 General ... 868
9.18.2 Operation upon entering a regulatory domain ... 869
9.18.3 Determination of hopping patterns for FH PHYs ... 869

9.18.4 Hopping sequence generation using the Frequency Hopping and Hopping Pattern Table elements ... 872
9.18.5 Operation with operating classes ... 873
9.18.6 Operation with coverage classes ... 873
9.19 HCF ... 873
9.19.1 General ... 873
9.19.2 HCF contention-based channel access (EDCA) ... 874
9.19.2.1 Reference implementation ... 874
9.19.2.2 EDCA TXOPs ... 874
9.19.2.3 Obtaining an EDCA TXOP ... 875
9.19.2.4 Multiple frame transmission in an EDCA TXOP ... 877
9.19.2.5 EDCA backoff procedure ... 878
9.19.2.6 Retransmit procedures ... 879
9.19.2.7 Truncation of TXOP ... 880
9.19.3 HCCA ... 881
9.19.3.1 General ... 881
9.19.3.2 HCCA procedure ... 882
9.19.3.3 TXOP structure and timing ... 884
9.19.3.4 NAV operation during a TXOP ... 885
9.19.3.5 HCCA transfer rules ... 886
9.19.4 Admission Control at the HC ... 888
9.19.4.1 General ... 888
9.19.4.2 Contention-based admission control procedures ... 888
9.19.4.3 Controlled-access admission control ... 890
9.20 Mesh coordination function (MCF) ... 892
9.20.1 General ... 892
9.20.2 MCF contention-based channel access ... 892
9.20.3 MCF controlled channel access (MCCA) ... 892
9.20.3.1 General ... 892
9.20.3.2 MCCA activation ... 893
9.20.3.3 MCCAOP reservations ... 893
9.20.3.4 Neighborhood MCCAOP periods at a mesh STA ... 895
9.20.3.5 MCCA access fraction (MAF) ... 895
9.20.3.6 MCCAOP setup procedure ... 896
9.20.3.7 MCCAOP advertisement ... 897
9.20.3.8 MCCAOP teardown ... 901
9.20.3.9 Access during MCCAOPs ... 902
9.20.3.10 Interaction with time synchronization ... 903
9.21 Block Acknowledgment (Block Ack) ... 904
9.21.1 Introduction ... 904
9.21.2 Setup and modification of the Block Ack parameters ... 905
9.21.3 Data and acknowledgment transfer using immediate Block Ack policy and delayed Block Ack policy ... 905
9.21.4 Receive buffer operation ... 908
9.21.5 Teardown of the Block Ack mechanism ... 909
9.21.6 Selection of BlockAck and BlockAckReq variants ... 909
9.21.7 HT-immediate Block Ack extensions ... 909
9.21.7.1 Introduction to HT-immediate Block Ack extensions ... 909
9.21.7.2 HT-immediate Block Ack architecture ... 910
9.21.7.3 Scoreboard context control during full-state operation ... 911
9.21.7.4 Scoreboard context control during partial-state operation ... 912
9.21.7.5 Generation and transmission of BlockAck by an HT STA ... 913
9.21.7.6 Receive reordering buffer control operation ... 913
9.21.7.7 Originator's behavior ... 915

9.21.7.8 Maintaining BlockAck state at the originator ... 916
9.21.7.9 Originator's support of recipient's partial state ... 916
9.21.8 HT-delayed Block Ack extensions ... 916
9.21.8.1 Introduction ... 916
9.21.8.2 HT-delayed Block Ack negotiation ... 916
9.21.8.3 Operation of HT-delayed Block Ack ... 916
9.21.9 Protected Block Ack Agreement ... 917
9.22 No Acknowledgment (No Ack) ... 917
9.23 Protection mechanisms ... 918
9.23.1 Introduction ... 918
9.23.2 Protection mechanism for non-ERP receivers ... 918
9.23.3 Protection mechanisms for transmissions of HT PPDUs ... 920
9.23.3.1 General ... 920
9.23.3.2 Protection rules for HT STA operating a direct link ... 922
9.23.3.3 RIFS protection ... 923
9.23.3.4 Use of OBSS Non-HT STAs Present field ... 923
9.23.3.5 Protection rules for an HT mesh STA in an MBSS ... 923
9.23.4 L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs ... 924
9.23.5 L-SIG TXOP protection ... 926
9.23.5.1 General rules ... 926
9.23.5.2 L-SIG TXOP protection rules at the TXOP holder ... 927
9.23.5.3 L-SIG TXOP protection rules at the TXOP responder ... 928
9.23.5.4 L-SIG TXOP protection NAV update rule ... 929
9.24 MAC frame processing ... 929
9.24.1 Introduction ... 929
9.24.2 Revision level field processing ... 929
9.24.3 Duration/ID field processing ... 929
9.24.4 Response to an invalid Action frame ... 929
9.24.5 Operation of the Dialog Token field ... 929
9.24.6 Element parsing ... 930
9.24.7 Vendor specific element parsing ... 930
9.24.8 Extensible element parsing ... 930
9.24.9 Extensible subelement parsing ... 930
9.25 Reverse Direction Protocol ... 930
9.25.1 Reverse direction (RD) exchange sequence ... 930
9.25.2 Support for RD ... 931
9.25.3 Rules for RD initiator ... 931
9.25.4 Rules for RD responder ... 932
9.26 PSMP Operation ... 933
9.26.1 Frame transmission mechanism during PSMP ... 933
9.26.1.1 PSMP frame transmission (PSMP-DTT and PSMP-UTT) ... 933
9.26.1.2 PSMP downlink transmission (PSMP-DTT) ... 934
9.26.1.3 PSMP uplink transmission (PSMP-UTT) ... 934
9.26.1.4 PSMP burst ... 937
9.26.1.5 Resource allocation within a PSMP burst ... 938
9.26.1.6 PSMP-UTT retransmission ... 939
9.26.1.7 PSMP acknowledgment rules ... 939
9.26.1.8 PSMP group addressed transmission rules ... 941
9.26.2 Scheduled PSMP ... 941
9.26.3 Unscheduled PSMP ... 942
9.27 Sounding PPDUs ... 942
9.28 Link adaptation ... 943
9.28.1 Introduction ... 943

9.28.2 Link adaptation using the HT Control field ... 943
9.29 Transmit beamforming ... 945
9.29.1 General ... 945
9.29.2 Transmit beamforming with implicit feedback ... 946
9.29.2.1 General ... 946
9.29.2.2 Unidirectional implicit transmit beamforming ... 947
9.29.2.3 Bidirectional implicit transmit beamforming ... 948
9.29.2.4 Calibration ... 949
9.29.3 Explicit feedback beamforming ... 954
9.30 Antenna selection (ASEL) ... 958
9.30.1 Introduction ... 958
9.30.2 Procedure ... 958
9.31 Null data packet (NDP) sounding ... 962
9.31.1 NDP rules ... 962
9.31.2 Transmission of an NDP ... 963
9.31.3 Determination of NDP destination ... 963
9.31.4 Determination of NDP source ... 964
9.32 Mesh forwarding framework ... 964
9.32.1 General ... 964
9.32.2 Forwarding information ... 964
9.32.3 Frame addressing in an MBSS ... 965
9.32.4 Addressing and forwarding of individually addressed Mesh Data frames ... 966
9.32.4.1 At source mesh STAs (individually addressed) ... 966
9.32.4.2 At intermediate and destination mesh STAs (individually addressed) ... 967
9.32.5 Addressing and forwarding of group addressed Mesh Data frames ... 968
9.32.5.1 At source mesh STAs (group addressed) ... 968
9.32.5.2 At recipient mesh STAs (group addressed) ... 969
9.32.6 Addressing of Management frames and MMPDU forwarding ... 970
9.32.6.1 General ... 970
9.32.6.2 MMPDU forwarding using individually addressed Multihop Action frames ... 970
9.32.6.3 MMPDU forwarding using group addressed Multihop Action frames ... 970
9.32.7 Detection of duplicate MSDUs/MMPDUs ... 971
9.32.8 Mesh STAs that do not forward ... 971
9.32.9 Frame forwarding and unknown destination ... 972

10. MLME ... 973

10.1 Synchronization ... 973
10.1.1 General ... 973
10.1.2 Basic approach ... 973
10.1.2.1 TSF for infrastructure networks ... 973
10.1.2.2 TSF for an IBSS ... 973
10.1.2.3 TSF for an MBSS ... 973
10.1.3 Maintaining synchronization ... 974
10.1.3.1 General ... 974
10.1.3.2 Beacon generation in infrastructure networks ... 974
10.1.3.3 Beacon generation in an IBSS ... 974
10.1.3.4 Beacon generation in an MBSS ... 975
10.1.3.5 Beacon reception ... 975
10.1.3.6 Multiple BSSID procedure ... 976
10.1.3.7 TSF timer accuracy ... 977

10.1.4 Acquiring synchronization, scanning ... 977
10.1.4.1 General ... 977
10.1.4.2 Passive scanning ... 978
10.1.4.3 Active scanning ... 978
10.1.4.4 Initializing a BSS ... 981
10.1.4.5 Synchronizing with a BSS ... 981
10.1.4.6 Operation of Supported Rates and Extended Supported Rates elements ... 982
10.1.5 Adjusting STA timers ... 983
10.1.6 Timing synchronization for FH PHYs ... 983
10.1.7 Terminating a BSS ... 983
10.1.8 Supported rates and extended supported rates advertisement ... 983
10.2 Power management ... 984
10.2.1 Power management in an infrastructure network ... 984
10.2.1.1 General ... 984
10.2.1.2 STA Power Management modes ... 985
10.2.1.3 AP TIM transmissions ... 985
10.2.1.4 TIM types ... 986
10.2.1.5 Power management with APSD ... 986
10.2.1.6 AP operation during the CP ... 989
10.2.1.7 AP operation during the CFP ... 992
10.2.1.8 Receive operation for STAs in PS mode during the CP ... 993
10.2.1.9 Receive operation for STAs in PS mode during the CFP ... 994
10.2.1.10 Receive operation using APSD ... 994
10.2.1.11 STAs operating in the Active mode ... 995
10.2.1.12 AP aging function ... 995
10.2.1.13 PSMP power management ... 995
10.2.1.14 TDLS Peer Power Save Mode ... 996
10.2.1.15 TDLS Peer U-APSD ... 998
10.2.1.16 FMS power management ... 1000
10.2.1.17 TIM Broadcast ... 1003
10.2.1.18 WNM-Sleep mode ... 1005
10.2.2 Power management in an IBSS ... 1006
10.2.2.1 Introduction ... 1006
10.2.2.2 Basic approach ... 1006
10.2.2.3 Initialization of power management within an IBSS ... 1008
10.2.2.4 STA power state transitions ... 1008
10.2.2.5 ATIM and frame transmission ... 1009
10.2.3 Power management in an MBSS ... 1010
10.2.4 SM power save ... 1010
10.3 STA authentication and association ... 1011
10.3.1 State variables ... 1011
10.3.2 State transition diagram for nonmesh STAs ... 1012
10.3.3 Frame filtering based on STA state ... 1012
10.3.4 Authentication and deauthentication ... 1013
10.3.4.1 General ... 1013
10.3.4.2 Authentication—originating STA ... 1014
10.3.4.3 Authentication—destination STA ... 1014
10.3.4.4 Deauthentication—originating STA ... 1015
10.3.4.5 Deauthentication—destination STA ... 1015
10.3.5 Association, reassociation, and disassociation ... 1016
10.3.5.1 General ... 1016
10.3.5.2 Non-AP STA association initiation procedures ... 1016
10.3.5.3 AP association receipt procedures ... 1017

10.3.5.4 Non-AP STA reassociation initiation procedures 1019
10.3.5.5 AP reassociation receipt procedures 1020
10.3.5.6 Non-AP STA disassociation initiation procedures 1021
10.3.5.7 Non-AP STA disassociation receipt procedure 1021
10.3.5.8 AP disassociation initiation procedure 1022
10.3.5.9 AP disassociation receipt procedure 1022
10.3.6 Additional mechanisms for an AP collocated with a mesh STA 1023
10.4 TS operation 1023
10.4.1 Introduction 1023
10.4.2 TSPEC construction 1024
10.4.3 TS life cycle 1024
10.4.4 TS setup 1025
10.4.5 TS setup by resource request during a fast BSS transition 1028
10.4.6 PSMP management 1028
10.4.7 Failed TS setup 1029
10.4.8 Data transfer 1029
10.4.9 TS deletion 1030
10.4.10 TS timeout 1031
10.4.11 TS suspension 1032
10.4.12 TS Reinstatement 1032
10.5 Block Ack operation 1032
10.5.1 Introduction 1032
10.5.2 Setup and modification of the Block Ack parameters 1032
10.5.2.1 General 1032
10.5.2.2 Procedure at the originator 1032
10.5.2.3 Procedure at the recipient 1034
10.5.2.4 Procedure common to both originator and recipient 1035
10.5.3 Teardown of the Block Ack mechanism 1035
10.5.3.1 General 1035
10.5.3.2 Procedure at the initiator of the Block Ack teardown 1035
10.5.3.3 Procedure at the recipient of the DELBA frame 1036
10.5.4 Error recovery upon a peer failure 1036
10.6 Higher layer timer synchronization 1036
10.6.1 Introduction 1036
10.6.2 Procedure at the STA 1038
10.7 DLS operation 1038
10.7.1 General 1038
10.7.2 DLS procedures 1039
10.7.2.1 General 1039
10.7.2.2 Setup procedure at the QoS STA 1039
10.7.2.3 Setup procedure at the AP 1040
10.7.2.4 Operation of the DLS Timeout Value field 1041
10.7.3 Data transfer after setup 1041
10.7.4 DLS teardown 1041
10.7.4.1 General 1041
10.7.4.2 STA-initiated DLS teardown procedure 1041
10.7.4.3 Teardown procedure at the AP 1043
10.7.4.4 AP-initiated DLS teardown procedure 1043
10.7.5 Error recovery upon a peer failure 1043
10.7.6 Secure DLS operation 1043
10.8 TPC procedures 1044
10.8.1 General 1044
10.8.2 Association based on transmit power capability 1045
10.8.3 Peering based on transmit power capability 1045

10.8.4 Specification of regulatory and local maximum transmit power levels 1045
10.8.5 Selection of a transmit power 1046
10.8.6 Adaptation of the transmit power 1046
10.9 DFS procedures 1046
10.9.1 General 1046
10.9.2 Association based on supported channels 1047
10.9.3 Quieting channels for testing 1048
10.9.4 Testing channels for radars 1048
10.9.5 Discontinuing operations after detecting radars 1048
10.9.6 Detecting radars 1048
10.9.7 Requesting and reporting of measurements 1048
10.9.8 Selecting and advertising a new channel 1050
10.9.8.1 General 1050
10.9.8.2 Selecting and advertising a new channel in an infrastructure BSS 1050
10.9.8.3 Selecting and advertising a new channel in an IBSS 1050
10.9.8.4 MBSS channel switching 1052
10.9.8.5 HT-greenfield transmissions in operating classes with behavior limits set of 16 1054
10.9.9 Channel Switch Announcement element operation 1055
10.10 Extended channel switching (ECS) 1055
10.10.1 General 1055
10.10.2 Advertising supported operating classes 1055
10.10.3 Selecting and advertising a new channel and/or operating class 1056
10.10.3.1 General 1056
10.10.3.2 Selecting and advertising a new channel in an infrastructure BSS 1056
10.10.3.3 Selecting and advertising a new channel in an IBSS 1057
10.10.3.4 Selecting and advertising a new channel in an MBSS 1057
10.11 Radio measurement procedures 1058
10.11.1 General 1058
10.11.2 Measurement on operating and nonoperating channels 1058
10.11.3 Measurement start time 1058
10.11.4 Measurement Duration 1059
10.11.5 Station responsibility for conducting measurements 1060
10.11.6 Requesting and reporting of measurements 1060
10.11.7 Repeated measurement request frames 1063
10.11.8 Triggered autonomous reporting 1063
10.11.9 Specific measurement usage 1065
10.11.9.1 Beacon Report 1065
10.11.9.2 Frame Report 1067
10.11.9.3 Channel Load Report 1068
10.11.9.4 Noise Histogram Report 1069
10.11.9.5 STA Statistics Report 1070
10.11.9.6 Location Configuration Information Report 1071
10.11.9.7 Measurement pause 1072
10.11.9.8 Transmit Stream/Category Measurement Report 1073
10.11.9.9 Location Civic report 1075
10.11.9.10 Location Identifier Report 1076
10.11.10 Usage of the neighbor report 1077
10.11.10.1 General 1077
10.11.10.2 Requesting a neighbor report 1078
10.11.10.3 Receiving a neighbor report 1078
10.11.11 Link Measurement 1078
10.11.12 Measurement of the RPI histogram 1078
10.11.13 Operation of the Max Transmit Power field 1079

10.11.14 Multiple BSSID Set 1079
10.11.15 Measurement Pilot generation and usage 1079
10.11.15.1 General 1079
10.11.15.2 Measurement Pilot generation by an AP 1080
10.11.15.3 Measurement Pilot usage by a STA 1082
10.11.16 Access Delay Measurement 1082
10.11.17 BSS Available Admission Capacity 1082
10.11.18 AP Channel Report 1083
10.11.19 Multicast diagnostic reporting 1083
10.12 DSE procedures 1084
10.12.1 General 1084
10.12.2 Enablement and deenablement 1085
10.12.2.1 General 1085
10.12.2.2 Enablement requester STA 1085
10.12.2.3 Enablement responder STA 1086
10.12.2.4 Deenablement requester STA 1086
10.12.2.5 Deenablement responder STA 1087
10.12.3 Registered STA operation 1087
10.12.4 Enabling STA operation with DSE 1087
10.12.5 Dependent STA operation with DSE 1088
10.13 Group addressed robust management frame procedures 1090
10.14 SA Query procedures 1090
10.15 20/40 MHz BSS operation 1090
10.15.1 Rules for operation in 20/40 MHz BSS 1090
10.15.2 Basic 20/40 MHz BSS functionality 1091
10.15.3 Channel selection methods for 20/40 MHz operation 1091
10.15.3.1 General 1091
10.15.3.2 Scanning requirements for a 20/40 MHz BSS 1091
10.15.3.3 Channel management at the AP and in an IBSS 1093
10.15.4 40 MHz PPDU transmission restrictions 1095
10.15.4.1 Fields used to determine 40 MHz PPDU transmission restrictions 1095
10.15.4.2 Infrastructure non-AP STA restrictions 1096
10.15.4.3 AP restrictions 1097
10.15.4.4 Restrictions on non-AP STAs that are not infrastructure BSS members 1098
10.15.5 Scanning requirements for 40-MHz-capable STA 1098
10.15.6 Exemption from OBSS scanning 1099
10.15.7 Communicating 20/40 BSS coexistence information 1100
10.15.8 Support of DSSS/CCK in 40 MHz 1100
10.15.9 STA CCA sensing in a 20/40 MHz BSS 1100
10.15.10 NAV assertion in 20/40 MHz BSS 1101
10.15.11 Signaling 40 MHz intolerance 1101
10.15.12 Switching between 40 MHz and 20 MHz 1101
10.16 Phased coexistence operation (PCO) 1103
10.16.1 General description of PCO 1103
10.16.2 Operation at a PCO active AP 1104
10.16.3 Operation at a PCO active non-AP STA 1106
10.17 20/40 BSS Coexistence Management frame usage 1106
10.18 RSNA A-MSDU procedures 1107
10.19 Public Action frame addressing 1107
10.20 STAs communicating data frames outside the context of a BSS 1107
10.21 Timing Advertisement 1109
10.21.1 Introduction 1109
10.21.2 Timing advertisement frame procedures 1109

10.21.3 UTC TSF Offset procedures 1109
10.22 Tunneled direct-link setup 1109
10.22.1 General 1109
10.22.2 TDLS payload 1111
10.22.3 TDLS Discovery 1111
10.22.4 TDLS direct-link establishment 1111
10.22.5 TDLS direct-link teardown 1113
10.22.6 TDLS channel switching 1114
10.22.6.1 General behavior on the off-channel 1116
10.22.6.2 Setting up a 40 MHz direct link 1117
10.22.6.3 TDLS channel switching and power saving 1118
10.23 Wireless network management procedures 1118
10.23.1 Wireless network management dependencies 1118
10.23.2 Event request and report procedures 1118
10.23.2.1 Event request and event report 1118
10.23.2.2 Transition event request and report 1120
10.23.2.3 RSNA event request and report 1121
10.23.2.4 Peer-to-Peer Link event request and report 1121
10.23.2.5 WNM Log event request and report 1122
10.23.2.6 Vendor Specific event request and report 1122
10.23.3 Diagnostic request and report procedures 1122
10.23.3.1 Diagnostic request and diagnostic report 1122
10.23.3.2 Configuration Profile report 1124
10.23.3.3 Manufacturer information STA report 1124
10.23.3.4 Association diagnostic 1124
10.23.3.5 IEEE 802.1X authentication diagnostic 1125
10.23.4 Location track procedures 1126
10.23.4.1 Location track configuration procedures 1126
10.23.4.2 Location track notification procedures 1128
10.23.5 Timing measurement procedure 1130
10.23.6 BSS transition management for network load balancing 1132
10.23.6.1 BSS Transition capability 1132
10.23.6.2 BSS transition management query 1132
10.23.6.3 BSS transition management request 1133
10.23.6.4 BSS transition management response 1134
10.23.7 FMS multicast rate processing 1136
10.23.8 Collocated interference reporting 1136
10.23.9 QoS Traffic capability procedure 1137
10.23.10 AC Station Count 1138
10.23.11 TFS procedures 1138
10.23.11.1 TFS capability 1138
10.23.11.2 TFS non-AP STA operation 1139
10.23.11.3 TFS AP operation 1139
10.23.12 BSS Max idle period management 1140
10.23.13 Proxy ARP (including Proxy Neighbor Discovery) service 1140
10.23.14 Channel usage procedures 1141
10.23.15 DMS procedures 1142
10.23.16 WNM-Notification 1144
10.24 WLAN interworking with external networks procedures 1144
10.24.1 General 1144
10.24.2 Interworking capabilities and information 1144
10.24.3 Interworking procedures: generic advertisement service (GAS) 1145
10.24.3.1 GAS Protocol 1145
10.24.3.2 ANQP procedures 1153

10.24.4 Interworking procedures: IEEE 802.21 MIH support 1156
10.24.5 Interworking procedures: interactions with SSPN 1157
10.24.5.1 General operation 1157
10.24.5.2 Authentication and cipher suites selection with SSPN 1157
10.24.5.3 Reporting and session control with SSPN 1158
10.24.6 Interworking procedures: emergency services support 1159
10.24.7 Interworking procedures: emergency alert system (EAS) support 1160
10.24.8 Interworking procedures: support for the advertisement of roaming consortiums 1161
10.24.9 Interworking procedures: support for QoS mapping from external networks 1161

11. Security 1163

11.1 Framework 1163
11.1.1 Classes of security algorithm 1163
11.1.2 Security methods 1163
11.1.3 RSNA equipment and RSNA capabilities 1163
11.1.4 RSNA establishment 1163
11.1.5 RSNA PeerKey Support 1165
11.1.6 RSNA assumptions and constraints 1165
11.1.7 Requirements for robust management frame protection 1166
11.1.8 Emergency service establishment in an RSN 1166
11.2 Pre-RSNA security methods 1167
11.2.1 Status of Pre-RSNA security methods 1167
11.2.2 Wired equivalent privacy (WEP) 1167
11.2.2.1 WEP overview 1167
11.2.2.2 WEP MPDU format 1167
11.2.2.3 WEP state 1168
11.2.2.4 WEP procedures 1168
11.2.3 Pre-RSNA authentication 1170
11.2.3.1 Overview 1170
11.2.3.2 Open System authentication 1170
11.2.3.3 Shared Key authentication 1171
11.3 Authentication using a password 1174
11.3.1 SAE overview 1174
11.3.2 Assumptions on SAE 1175
11.3.3 Representation of a password 1175
11.3.4 Finite cyclic groups 1176
11.3.4.1 General 1176
11.3.4.2 Elliptic curve cryptography (ECC) groups 1176
11.3.4.3 Finite field cryptography (FFC) groups 1178
11.3.5 SAE protocol 1179
11.3.5.1 Message exchanges 1179
11.3.5.2 PWE and secret generation 1180
11.3.5.3 Construction of a Commit Message 1180
11.3.5.4 Processing of a peer's Commit Message 1180
11.3.5.5 Construction of a Confirm Message 1181
11.3.5.6 Processing of a peer's Confirm Message 1181
11.3.6 Anti-clogging tokens 1181
11.3.7 Framing of SAE 1182
11.3.7.1 General 1182
11.3.7.2 Data type conversion 1182
11.3.7.3 Authentication transaction sequence number for SAE 1183
11.3.7.4 Encoding and decoding of Commit Messages 1183

11.3.7.5 Encoding and decoding of Confirm Messages 1184
11.3.7.6 Status codes 1184
11.3.8 SAE finite state machine 1184
11.3.8.1 General 1184
11.3.8.2 States 1185
11.3.8.3 Events and output 1186
11.3.8.4 Timers 1186
11.3.8.5 Variables 1187
11.3.8.6 Behavior of state machine 1187
11.4 RSNA confidentiality and integrity protocols 1191
11.4.1 Overview 1191
11.4.2 Temporal Key Integrity Protocol (TKIP) 1191
11.4.2.1 TKIP overview 1191
11.4.2.2 TKIP MPDU formats 1193
11.4.2.3 TKIP MIC 1194
11.4.2.4 TKIP countermeasures procedures 1197
11.4.2.5 TKIP mixing function 1201
11.4.2.6 TKIP replay protection procedures 1205
11.4.3 CTR with CBC-MAC Protocol (CCMP) 1205
11.4.3.1 General 1205
11.4.3.2 CCMP MPDU format 1206
11.4.3.3 CCMP cryptographic encapsulation 1207
11.4.3.4 CCMP decapsulation 1210
11.4.4 Broadcast/Multicast Integrity Protocol (BIP) 1212
11.4.4.1 BIP overview 1212
11.4.4.2 BIP MMPDU format 1212
11.4.4.3 BIP AAD construction 1212
11.4.4.4 BIP replay protection 1213
11.4.4.5 BIP transmission 1213
11.4.4.6 BIP reception 1213
11.5 RSNA security association management 1214
11.5.1 Security associations 1214
11.5.1.1 Security association definitions 1214
11.5.1.2 TPKSA 1219
11.5.1.3 Security association life cycle 1219
11.5.2 RSNA selection 1222
11.5.3 RSNA policy selection in an ESS 1222
11.5.4 TSN policy selection in an ESS 1224
11.5.5 RSNA policy selection in an IBSS and for DLS 1224
11.5.6 TSN policy selection in an IBSS 1225
11.5.7 RSNA policy selection in an MBSS 1226
11.5.8 RSN management of the IEEE 802.1X Controlled Port 1226
11.5.9 RSNA authentication in an ESS 1227
11.5.9.1 General 1227
11.5.9.2 Preauthentication and RSNA key management 1227
11.5.9.3 Cached PMKSAs and RSNA key management 1228
11.5.10 RSNA authentication in an IBSS 1228
11.5.11 RSNA authentication in an MBSS 1230
11.5.12 RSNA key management in an ESS 1230
11.5.13 RSNA key management in an IBSS 1231
11.5.14 RSNA key management in an MBSS 1231
11.5.15 RSNA security association termination 1232
11.5.16 Protection of robust management frames 1232
11.5.17 Robust management frame selection procedure 1233

11.6 Keys and key distribution ... 1234
11.6.1 Key hierarchy ... 1234
11.6.1.1 General ... 1234
11.6.1.2 PRF ... 1235
11.6.1.3 Pairwise key hierarchy ... 1236
11.6.1.4 Group key hierarchy ... 1237
11.6.1.5 Integrity group key hierarchy ... 1238
11.6.1.6 PeerKey key hierarchy ... 1239
11.6.1.7 FT key hierarchy ... 1240
11.6.2 EAPOL-Key frames ... 1244
11.6.3 EAPOL-Key frame construction and processing ... 1252
11.6.4 EAPOL-Key frame notation ... 1253
11.6.5 Nonce generation ... 1254
11.6.6 4-Way Handshake ... 1254
11.6.6.1 General ... 1254
11.6.6.2 4-Way Handshake Message 1 ... 1255
11.6.6.3 4-Way Handshake Message 2 ... 1256
11.6.6.4 4-Way Handshake Message 3 ... 1258
11.6.6.5 4-Way Handshake Message 4 ... 1260
11.6.6.6 4-Way Handshake implementation considerations ... 1261
11.6.6.7 Sample 4-Way Handshake ... 1262
11.6.6.8 4-Way Handshake analysis ... 1262
11.6.7 Group Key Handshake ... 1264
11.6.7.1 General ... 1264
11.6.7.2 Group Key Handshake Message 1 ... 1265
11.6.7.3 Group Key Handshake Message 2 ... 1266
11.6.7.4 Group Key Handshake implementation considerations ... 1267
11.6.7.5 Sample Group Key Handshake ... 1267
11.6.8 PeerKey Handshake ... 1268
11.6.8.1 General ... 1268
11.6.8.2 SMK Handshake ... 1268
11.6.8.3 PeerKey setup and handshake error conditions ... 1274
11.6.8.4 STKSA rekeying ... 1274
11.6.8.5 Error Reporting ... 1275
11.6.9 TDLS Peer Key security protocol ... 1276
11.6.9.1 General ... 1276
11.6.9.2 TDLS Peer Key Handshake ... 1277
11.6.9.3 TDLS Peer Key Handshake security assumptions ... 1278
11.6.9.4 TDLS Peer Key (TPK) Security Protocol Handshake messages ... 1279
11.6.9.5 Supplicant state machine procedures ... 1282
11.6.9.6 Supplicant PeerKey state machine states ... 1284
11.6.9.7 Supplicant PeerKey state machine variables ... 1286
11.6.10 RSNA Supplicant key management state machine ... 1287
11.6.10.1 General ... 1287
11.6.10.2 Supplicant state machine states ... 1287
11.6.10.3 Supplicant state machine variables ... 1288
11.6.11 RSNA Authenticator key management state machine ... 1289
11.6.11.1 General ... 1289
11.6.11.2 Authenticator state machine states ... 1292
11.6.11.3 Authenticator state machine variables ... 1293
11.6.11.4 Authenticator state machine procedures ... 1295
11.7 Mapping EAPOL keys to IEEE 802.11 keys ... 1295
11.7.1 Mapping PTK to TKIP keys ... 1295
11.7.2 Mapping GTK to TKIP keys ... 1295

11.7.3 Mapping PTK to CCMP keys 1295
11.7.4 Mapping GTK to CCMP keys 1296
11.7.5 Mapping GTK to WEP-40 keys 1296
11.7.6 Mapping GTK to WEP-104 keys 1296
11.7.7 Mapping IGTK to BIP keys 1296
11.8 Per-frame pseudo-code 1296
11.8.1 WEP frame pseudo-code 1296
11.8.2 RSNA frame pseudo-code 1298
11.8.2.1 General 1298
11.8.2.2 Per-MSDU/Per-A-MSDU Tx pseudo-code 1298
11.8.2.3 Per-MMPDU Tx pseudo-code 1299
11.8.2.4 Per-MPDU Tx pseudo-code 1300
11.8.2.5 Per-MPDU Tx pseudo-code for MMPDU 1301
11.8.2.6 Per-MPDU Rx pseudo-code 1301
11.8.2.7 Per-MPDU Rx pseudo-code for an MMPDU 1302
11.8.2.8 Per-MSDU/Per-A-MSDU Rx pseudo-code 1305
11.8.2.9 Per-MMPDU Rx pseudo-code 1306
11.9 Authenticated mesh peering exchange (AMPE) 1307

12. Fast BSS transition 1308

12.1 Overview 1308
12.2 Key holders 1308
12.2.1 Introduction 1308
12.2.2 Authenticator key holders 1309
12.2.3 Supplicant key holders 1310
12.3 Capability and policy advertisement 1310
12.4 FT initial mobility domain association 1311
12.4.1 Overview 1311
12.4.2 FT initial mobility domain association in an RSN 1311
12.4.3 FT initial mobility domain association in a non-RSN 1314
12.5 FT Protocol 1315
12.5.1 Overview 1315
12.5.2 Over-the-air FT Protocol authentication in an RSN 1315
12.5.3 Over-the-DS FT Protocol authentication in an RSN 1316
12.5.4 Over-the-air FT Protocol authentication in a non-RSN 1319
12.5.5 Over-the-DS FT Protocol authentication in a non-RSN 1320
12.6 FT Resource Request Protocol 1321
12.6.1 Overview 1321
12.6.2 Over-the-air fast BSS transition with resource request 1321
12.6.3 Over-the-DS fast BSS transition with resource request 1323
12.7 FT reassociation 1325
12.7.1 FT reassociation in an RSN 1325
12.7.2 FT reassociation in a non-RSN 1327
12.8 FT authentication sequence 1328
12.8.1 Overview 1328
12.8.2 FT authentication sequence: contents of first message 1329
12.8.3 FT authentication sequence: contents of second message 1329
12.8.4 FT authentication sequence: contents of third message 1330
12.8.5 FT authentication sequence: contents of fourth message 1330
12.9 FT security architecture state machines 1332
12.9.1 Introduction 1332
12.9.2 R0KH state machine 1332
12.9.2.1 General 1332

12.9.2.2 R0KH state machine states 1333
12.9.2.3 R0KH state machine variables 1334
12.9.2.4 R0KH state machine procedures 1334
12.9.3 R1KH state machine 1334
12.9.3.1 General 1334
12.9.3.2 R1KH state machine states 1336
12.9.3.3 R1KH state machine variables 1337
12.9.3.4 R1KH state machine procedures 1338
12.9.4 S0KH state machine 1338
12.9.4.1 General 1338
12.9.4.2 S0KH state machine states 1339
12.9.4.3 S0KH state machine variables 1339
12.9.4.4 S0KH state machine procedures 1339
12.9.5 S1KH state machine 1339
12.9.5.1 General 1339
12.9.5.2 S1KH state machine states 1342
12.9.5.3 S1KH state machine variables 1343
12.9.5.4 S1KH state machine procedures 1343
12.10 Remote request broker (RRB) communication 1343
12.10.1 Overview 1343
12.10.2 Remote request broker (RRB) 1344
12.10.3 Remote Request/Response frame definition 1344
12.11 Resource request procedures 1345
12.11.1 General 1345
12.11.2 Resource information container (RIC) 1346
12.11.3 Creation and handling of a resource request 1348
12.11.3.1 FTO procedures 1348
12.11.3.2 AP procedures 1349

13. MLME mesh procedures 1352

13.1 Mesh STA dependencies 1352
13.2 Mesh discovery 1352
13.2.1 General 1352
13.2.2 Mesh identifier 1352
13.2.3 Mesh profile 1353
13.2.4 Mesh STA configuration 1353
13.2.5 Supplemental information for the mesh discovery 1353
13.2.6 Scanning mesh BSSs 1354
13.2.7 Candidate peer mesh STA 1354
13.2.8 Establishing or becoming a member of a mesh BSS 1354
13.2.9 Establishing mesh peerings 1355
13.3 Mesh peering management (MPM) 1356
13.3.1 General 1356
13.3.2 State variable management 1357
13.3.3 Mesh authentication 1357
13.3.4 Mesh peering instance controller 1358
13.3.4.1 Overview 1358
13.3.4.2 Creating a new mesh peering instance 1358
13.3.4.3 Deleting mesh peering instances 1359
13.3.5 Mesh peering instance selection 1359
13.3.6 Mesh peering open 1360
13.3.6.1 Generating Mesh Peering Open frames 1360
13.3.6.2 Mesh Peering Open frame processing 1360

13.3.7 Mesh peering confirm 1361
13.3.7.1 Generating Mesh Peering Confirm frames 1361
13.3.7.2 Mesh Peering Confirm frame processing 1361
13.3.8 Mesh peering close 1361
13.3.8.1 Generating Mesh Peering Close frames 1361
13.3.8.2 Mesh Peering Close frame processing 1361
13.4 Mesh peering management finite state machine (MPM FSM) 1361
13.4.1 General 1361
13.4.2 States 1361
13.4.3 Events and actions 1362
13.4.4 Timers 1363
13.4.5 State transitions 1364
13.4.6 IDLE state 1365
13.4.7 OPN_SNT state 1366
13.4.8 CNF_RCVD state 1366
13.4.9 OPN_RCVD state 1367
13.4.10 ESTAB state 1368
13.4.11 HOLDING state 1368
13.5 Authenticated mesh peering exchange (AMPE) 1368
13.5.1 Overview 1368
13.5.2 Security capabilities selection 1369
13.5.2.1 Instance Pairwise Cipher Suite selection 1369
13.5.2.2 Group cipher suite selection 1369
13.5.3 Construction and processing AES-SIV-protected Mesh Peering Management frames 1370
13.5.4 Distribution of group transient keys in an MBSS 1371
13.5.5 Mesh Peering Management frames for AMPE 1371
13.5.5.1 General 1371
13.5.5.2 Mesh peering open for AMPE 1371
13.5.5.3 Mesh peering confirm for AMPE 1372
13.5.5.4 Mesh peering close for AMPE 1372
13.5.6 AMPE finite state machine 1373
13.5.6.1 Overview 1373
13.5.6.2 Additional events and actions to MPM FSM 1373
13.5.6.3 State transitions 1374
13.5.7 Keys and key derivation algorithm for the authenticated mesh peering exchange (AMPE) 1376
13.6 Mesh group key handshake 1377
13.6.1 General 1377
13.6.2 Protection on mesh group key handshake frames 1377
13.6.3 Mesh Group Key Inform frame construction and processing 1378
13.6.4 Mesh Group Key Acknowledge frame construction and processing 1379
13.6.5 Mesh group key implementation considerations 1380
13.7 Mesh security 1380
13.8 Mesh path selection and metric framework 1380
13.8.1 General 1380
13.8.2 Extensible path selection framework 1380
13.8.3 Link metric reporting 1381
13.9 Airtime link metric 1381
13.10 Hybrid wireless mesh protocol (HWMP) 1382
13.10.1 General 1382
13.10.2 Terminology 1383
13.10.3 On-demand path selection mode 1385
13.10.4 Proactive tree building mode 1386

13.10.4.1 General ... 1386
13.10.4.2 Proactive PREQ mechanism ... 1386
13.10.4.3 Proactive RANN mechanism ... 1386
13.10.5 Collocated STAs ... 1387
13.10.6 Parameters for extensible path selection framework ... 1387
13.10.7 Addressing of HWMP Mesh Path Selection frame ... 1387
13.10.8 General rules for processing HWMP elements ... 1389
13.10.8.1 General ... 1389
13.10.8.2 HWMP propagation ... 1389
13.10.8.3 HWMP sequence numbering ... 1389
13.10.8.4 Forwarding information ... 1390
13.10.8.5 Repeated attempts at path discovery ... 1391
13.10.8.6 Limiting the rate of HWMP SN increments ... 1392
13.10.9 Path request (PREQ) ... 1392
13.10.9.1 General ... 1392
13.10.9.2 Function ... 1392
13.10.9.3 Conditions for generating and sending a PREQ element ... 1392
13.10.9.4 PREQ element processing ... 1400
13.10.10 Path reply (PREP) ... 1402
13.10.10.1 General ... 1402
13.10.10.2 Function ... 1402
13.10.10.3 Conditions for generating and sending a PREP element ... 1402
13.10.10.4 PREP element processing ... 1405
13.10.11 Path error (PERR) ... 1406
13.10.11.1 General ... 1406
13.10.11.2 Function ... 1406
13.10.11.3 Conditions for generating and sending a PERR element ... 1406
13.10.11.4 PERR element processing ... 1410
13.10.12 Root announcement (RANN) ... 1410
13.10.12.1 General ... 1410
13.10.12.2 Function ... 1411
13.10.12.3 Conditions for generating and sending a RANN element ... 1411
13.10.12.4 RANN element reception ... 1412
13.10.13 Considerations for support of STAs without mesh functionality ... 1413
13.11 Interworking with the DS ... 1413
13.11.1 Overview of interworking between a mesh BSS and a DS ... 1413
13.11.2 Gate announcement (GANN) ... 1414
13.11.2.1 General ... 1414
13.11.2.2 Function ... 1414
13.11.2.3 Conditions for generating and sending a GANN element ... 1414
13.11.2.4 GANN element processing ... 1415
13.11.3 Data forwarding at proxy mesh gates ... 1416
13.11.3.1 General ... 1416
13.11.3.2 Forwarding of MSDUs from the MBSS to the DS ... 1416
13.11.3.3 Forwarding of MSDUs from the DS to the MBSS ... 1416
13.11.4 Proxy information and proxy update ... 1418
13.11.4.1 General ... 1418
13.11.4.2 Proxy information ... 1418
13.11.4.3 Proxy update (PXU) ... 1419
13.11.4.4 Proxy update confirmation (PXUC) ... 1421
13.11.5 Mesh STA collocation ... 1422
13.12 Intra-mesh congestion control ... 1422
13.12.1 General ... 1422
13.12.2 Congestion control signaling protocol ... 1422

13.13 Synchronization and beaconing in MBSSs ... 1423
13.13.1 TSF for MBSSs ... 1423
13.13.2 Extensible synchronization framework ... 1423
13.13.2.1 General ... 1423
13.13.2.2 Neighbor offset synchronization method ... 1423
13.13.3 Beaconing ... 1426
13.13.3.1 Beacon generation in MBSSs ... 1426
13.13.3.2 Beacon reception for mesh STA ... 1426
13.13.4 Mesh beacon collision avoidance (MBCA) ... 1426
13.13.4.1 Overview ... 1426
13.13.4.2 Beacon timing advertisement ... 1427
13.13.4.3 TBTT selection ... 1430
13.13.4.4 TBTT adjustment ... 1430
13.13.4.5 Frame transmission across reported TBTT ... 1432
13.13.4.6 Delayed beacon transmissions ... 1432
13.14 Power save in a mesh BSS ... 1432
13.14.1 General ... 1432
13.14.2 Mesh power modes ... 1433
13.14.2.1 General ... 1433
13.14.2.2 Peer-specific mesh power modes ... 1433
13.14.2.3 Nonpeer mesh power modes ... 1434
13.14.3 Mesh power mode indications and transitions ... 1434
13.14.3.1 General ... 1434
13.14.3.2 Transition to a higher activity level ... 1435
13.14.3.3 Transition to a lower activity level ... 1435
13.14.4 TIM transmissions in an MBSS ... 1435
13.14.5 TIM types ... 1435
13.14.6 Mesh awake window ... 1436
13.14.7 Power save support ... 1436
13.14.8 Operation in peer-specific and nonpeer mesh power modes ... 1437
13.14.8.1 General ... 1437
13.14.8.2 Operation in active mode ... 1437
13.14.8.3 Operation in deep sleep mode for nonpeer mesh STAs ... 1437
13.14.8.4 Operation in light sleep mode for a mesh peering ... 1438
13.14.8.5 Operation in deep sleep mode for a mesh peering ... 1438
13.14.8.6 Conditions for Doze state ... 1438
13.14.9 Mesh peer service periods ... 1439
13.14.9.1 General ... 1439
13.14.9.2 Initiation of a mesh peer service period ... 1439
13.14.9.3 Operation during a mesh peer service period ... 1440
13.14.9.4 Termination of a mesh peer service period ... 1440
13.14.10 MCCA use by power saving mesh STA ... 1441

14. Frequency-Hopping spread spectrum (FHSS) PHY specification for the 2.4 GHz industrial, scientific, and medical (ISM) band ... 1442

14.1 Status of the Frequency Hopping PHY ... 1442
14.2 Overview ... 1442
14.2.1 Overview of FHSS PHY ... 1442
14.2.2 FHSS PHY functions ... 1442
14.2.2.1 General ... 1442
14.2.2.2 PLCP sublayer ... 1442
14.2.2.3 PLME ... 1442
14.2.2.4 PMD sublayer ... 1442

14.2.3 Service specification method and notation 1443
14.3 FHSS PHY-specific service parameter lists 1443
14.3.1 Overview 1443
14.3.2 TXVECTOR parameters 1443
14.3.2.1 General 1443
14.3.2.2 TXVECTOR LENGTH 1443
14.3.2.3 TXVECTOR DATARATE 1444
14.3.3 RXVECTOR parameters 1444
14.3.3.1 General 1444
14.3.3.2 TRXVECTOR LENGTH 1444
14.3.3.3 RXVECTOR RSSI 1444
14.4 FHSS PLCP sublayer 1444
14.4.1 Overview 1444
14.4.2 State diagram notation 1444
14.4.3 PLCP frame format 1446
14.4.3.1 General 1446
14.4.3.2 PLCP Preamble field 1446
14.4.3.3 PLCP Header field 1446
14.4.3.4 PLCP data whitener 1447
14.4.4 PLCP state machines 1448
14.4.4.1 General 1448
14.4.4.2 Transmit PLCP 1448
14.4.4.3 CS/CCA procedure 1452
14.4.4.4 Receive PLCP 1455
14.5 PLME SAP layer management 1458
14.5.1 Overview 1458
14.5.2 FH PHY specific MLME procedures 1458
14.5.2.1 Overview 1458
14.5.2.2 FH synchronization 1458
14.5.3 FH PLME state machines 1458
14.5.3.1 Overview 1458
14.5.3.2 PLME state machine 1458
14.5.3.3 PLME management primitives 1460
14.6 FHSS PMD sublayer services 1461
14.6.1 Scope and field of application 1461
14.6.2 Overview of services 1461
14.6.3 Overview of interactions 1461
14.6.4 Basic service and options 1461
14.6.4.1 General 1461
14.6.4.2 PMD_SAP peer-to-peer service primitives 1461
14.6.4.3 PMD_SAP sublayer-to-sublayer service primitives 1462
14.6.4.4 PMD_SAP service primitives parameters 1462
14.6.5 PMD_SAP detailed service specification 1462
14.6.5.1 Introduction 1462
14.6.5.2 PMD_DATA.request 1462
14.6.5.3 PMD_DATA.indication 1463
14.6.5.4 PMD_TXRX.request 1463
14.6.5.5 PMD_PA_RAMP.request 1464
14.6.5.6 PMD_ANTSEL.request 1464
14.6.5.7 PMD_TXPWRLVL.request 1465
14.6.5.8 PMD_FREQ.request 1466
14.6.5.9 PMD_RSSI.indication 1466
14.6.5.10 PMD_PWRMGMT.request 1467

14.7 FHSS PMD sublayer, 1.0 Mb/s 1467
14.7.1 1 Mb/s PMD operating specifications, general 1467
14.7.2 Regulatory requirements 1467
14.7.3 Operating frequency range 1468
14.7.4 Number of operating channels 1468
14.7.5 Operating channel center frequency 1468
14.7.6 Occupied channel bandwidth 1471
14.7.7 Minimum hop rate 1471
14.7.8 Hop sequences 1471
14.7.9 Unwanted emissions 1473
14.7.10 Modulation 1473
14.7.11 Channel data rate 1475
14.7.12 Channel switching/settling time 1475
14.7.13 Receive to transmit switch time 1475
14.7.14 PMD transmit specifications 1475
14.7.14.1 Introduction 1475
14.7.14.2 Nominal transmit power 1475
14.7.14.3 Transmit power levels 1475
14.7.14.4 Transmit power level control 1475
14.7.14.5 Transmit spectrum shape 1475
14.7.14.6 Transmit center frequency tolerance 1476
14.7.14.7 Transmitter ramp periods 1476
14.7.15 PMD receiver specifications 1476
14.7.15.1 Introduction 1476
14.7.15.2 Input signal range 1476
14.7.15.3 Receive center frequency acceptance range 1476
14.7.15.4 CCA power threshold 1476
14.7.15.5 Receiver sensitivity 1477
14.7.15.6 Intermodulation 1477
14.7.15.7 Desensitization (Dp) 1477
14.7.15.8 Receiver radiation 1477
14.8 FHSS PMD sublayer, 2.0 Mb/s 1478
14.8.1 Overview 1478
14.8.2 4GFSK modulation 1478
14.8.3 Frame structure for HS FHSS PHY 1479
14.8.4 Channel data rate 1479
14.8.5 Input dynamic range 1480
14.8.6 Receiver sensitivity 1480
14.8.7 IMp 1480
14.8.8 Dp 1480
14.9 FHSS PHY MIB 1480
14.9.1 FH PHY attributes 1480
14.9.2 FH PHY attribute definitions 1482
14.9.2.1 dot11PHYType 1482
14.9.2.2 dot11RegDomainsImplementedValue 1482
14.9.2.3 dot11CurrentRegDomain 1483
14.9.2.4 dot11CurrentPowerState 1483
14.9.2.5 dot11SupportedDataRatesTX 1483
14.9.2.6 dot11SupportedDataRatesRX 1483
14.9.2.7 aMPDUMaxLength 1483
14.9.2.8 dot11TxAntennaImplemented 1484
14.9.2.9 dot11CurrentTxAntenna 1484
14.9.2.10 dot11RxAntennaImplemented 1484
14.9.2.11 dot11DiversitySupportImplemented 1485

14.9.2.12 dot11DiversitySelectionRxImplemented 1485
14.9.2.13 dot11NumberSupportedPowerLevelsImplemented 1485
14.9.2.14 dot11TxPowerLevel1-8 1485
14.9.2.15 dot11CurrentTxPowerLevel 1486
14.9.2.16 dot11HopTime 1486
14.9.2.17 dot11CurrentChannelNumber 1486
14.9.2.18 dot11MaxDwellTime 1486
14.9.2.19 dot11CurrentSet 1486
14.9.2.20 dot11CurrentPattern 1486
14.9.2.21 dot11CurrentIndex 1487
14.9.2.22 dot11CurrentPowerState 1487
14.10 FH PHY characteristics 1487

15. Infrared (IR) PHY specification 1489

15.1 Status of the Infrared PHY 1489
15.2 Overview 1489
15.2.1 General 1489
15.2.2 Scope 1490
15.2.3 IR PHY functions 1490
15.2.3.1 General 1490
15.2.3.2 PLCP sublayer 1490
15.2.3.3 PMD sublayer 1490
15.2.3.4 PLME 1490
15.2.4 Service specification method and notation 1490
15.3 IR PLCP sublayer 1491
15.3.1 General 1491
15.3.2 Overview 1491
15.3.3 PLCP frame format 1491
15.3.4 PLCP modulation and rate change 1491
15.3.5 PLCP field definitions 1492
15.3.5.1 PLCP SYNC field 1492
15.3.5.2 PLCP SFD field 1492
15.3.5.3 PLCP DR field 1492
15.3.5.4 PLCP DCLA field 1492
15.3.5.5 PLCP LENGTH field 1493
15.3.5.6 PLCP CRC field 1493
15.3.5.7 PSDU field 1493
15.3.6 PLCPs 1493
15.3.6.1 Transmit PLCP 1493
15.3.6.2 Receive PLCP 1494
15.3.6.3 CCA procedure 1494
15.3.6.4 PMD_SAP peer-to-peer service primitive parameters 1494
15.4 IR PMD sublayer 1495
15.4.1 General 1495
15.4.2 Overview 1495
15.4.3 PMD operating specifications, general 1495
15.4.3.1 General 1495
15.4.3.2 Modulation and channel data rates 1495
15.4.3.3 Octet partition and PPM symbol generation procedure 1496
15.4.3.4 Operating environment 1496
15.4.4 PMD transmit specifications 1497
15.4.4.1 Introduction 1497
15.4.4.2 Transmitted peak optical power 1497

15.4.4.3 Basic pulse shape and parameters ... 1497
15.4.4.4 Emitter radiation pattern mask ... 1498
15.4.4.5 Optical emitter peak wavelength ... 1500
15.4.4.6 Transmit spectrum mask ... 1500
15.4.5 PMD receiver specifications ... 1500
15.4.5.1 Introduction ... 1500
15.4.5.2 Receiver sensitivity ... 1500
15.4.5.3 Receiver dynamic range ... 1501
15.4.5.4 Receiver field of view (FOV) ... 1501
15.4.6 ED, CS, and CCA definitions ... 1501
15.4.6.1 ED signal ... 1501
15.4.6.2 CS signal ... 1501
15.4.6.3 CCA ... 1502
15.4.6.4 CHNL_ID ... 1502
15.5 PHY attributes ... 1502

16. DSSS PHY specification for the 2.4 GHz band designated for ISM applications ... 1504

16.1 Overview ... 1504
16.1.1 General ... 1504
16.1.2 Scope ... 1504
16.1.3 DSSS PHY functions ... 1504
16.1.3.1 General ... 1504
16.1.3.2 PLCP sublayer ... 1504
16.1.3.3 PMD sublayer ... 1504
16.1.3.4 PLME ... 1504
16.1.4 Service specification method and notation ... 1505
16.2 DSSS PLCP sublayer ... 1505
16.2.1 Overview ... 1505
16.2.2 PLCP frame format ... 1505
16.2.3 PLCP field definitions ... 1505
16.2.3.1 General ... 1505
16.2.3.2 PLCP SYNC field ... 1505
16.2.3.3 PLCP SFD ... 1506
16.2.3.4 PLCP IEEE 802.11 SIGNAL field ... 1506
16.2.3.5 PLCP IEEE 802.11 SERVICE field ... 1506
16.2.3.6 PLCP LENGTH field ... 1506
16.2.3.7 PLCP CRC field ... 1506
16.2.4 PLCP/DSSS PHY data scrambler and descrambler ... 1508
16.2.5 PLCP data modulation and modulation rate change ... 1508
16.2.6 Transmit PLCP ... 1508
16.2.7 Receive PLCP ... 1510
16.3 DSSS PLME ... 1513
16.3.1 PLME_SAP sublayer management primitives ... 1513
16.3.2 DSSS PHY MIB ... 1513
16.3.3 DS PHY characteristics ... 1514
16.4 DSSS PMD sublayer ... 1515
16.4.1 Scope and field of application ... 1515
16.4.2 Overview of service ... 1515
16.4.3 Overview of interactions ... 1516
16.4.4 Basic service and options ... 1516
16.4.4.1 General ... 1516
16.4.4.2 PMD_SAP peer-to-peer service primitives ... 1516
16.4.4.3 PMD_SAP peer-to-peer service primitive parameters ... 1516

16.4.4.4 PMD_SAP sublayer-to-sublayer service primitives 1518
16.4.4.5 PMD_SAP service primitive parameters 1518
16.4.5 PMD_SAP detailed service specification 1519
16.4.5.1 Introduction 1519
16.4.5.2 PMD_DATA.request 1519
16.4.5.3 PMD_DATA.indication 1519
16.4.5.4 PMD_TXSTART.request 1520
16.4.5.5 PMD_TXEND.request 1520
16.4.5.6 PMD_ANTSEL.request 1520
16.4.5.7 PMD_ANTSEL.indication 1521
16.4.5.8 PMD_TXPWRLVL.request 1521
16.4.5.9 PMD_RATE.request 1522
16.4.5.10 PMD_RATE.indication 1523
16.4.5.11 PMD_RSSI.indication 1523
16.4.5.12 PMD_SQ.indication 1524
16.4.5.13 PMD_CS.indication 1524
16.4.5.14 PMD_ED.indication 1525
16.4.5.15 PMD_ED.request 1525
16.4.5.16 PHY-CCA.indication 1526
16.4.5.17 PMD_RCPI.indication 1526
16.4.6 PMD operating specifications, general 1527
16.4.6.1 General 1527
16.4.6.2 Operating frequency range 1527
16.4.6.3 Channel Numbering of operating channels 1527
16.4.6.4 Spreading sequence 1528
16.4.6.5 Modulation and channel data rates 1528
16.4.6.6 Transmit and receive in-band and out-of-band spurious emissions 1528
16.4.6.7 TX-to-RX turnaround time 1528
16.4.6.8 RX-to-TX turnaround time 1529
16.4.6.9 Slot time 1529
16.4.6.10 Transmit and receive antenna port impedance 1529
16.4.7 PMD transmit specifications 1529
16.4.7.1 Introduction 1529
16.4.7.2 Transmit power levels 1529
16.4.7.3 Minimum transmitted power level 1529
16.4.7.4 Transmit power level control 1529
16.4.7.5 Transmit spectrum mask 1529
16.4.7.6 Transmit center frequency tolerance 1530
16.4.7.7 Chip clock frequency tolerance 1530
16.4.7.8 Transmit power-on and power-down ramp 1530
16.4.7.9 RF carrier suppression 1531
16.4.7.10 Transmit modulation accuracy 1531
16.4.7.11 Time of Departure accuracy 1533
16.4.8 PMD receiver specifications 1534
16.4.8.1 Introduction 1534
16.4.8.2 Receiver minimum input level sensitivity 1534
16.4.8.3 Receiver maximum input level 1534
16.4.8.4 Receiver adjacent channel rejection 1534
16.4.8.5 CCA 1534
16.4.8.6 Received Channel Power Indicator Measurement 1535

17. High Rate direct sequence spread spectrum (HR/DSSS) PHY specification 1536

17.1 Overview 1536
17.1.1 General 1536
17.1.2 Scope 1536
17.1.3 High Rate PHY functions 1537
17.1.3.1 General 1537
17.1.3.2 PLCP sublayer 1537
17.1.3.3 PMD sublayer 1537
17.1.3.4 PLME 1537
17.1.4 Service specification method and notation 1537
17.2 High Rate PLCP sublayer 1537
17.2.1 Overview 1537
17.2.2 PPDU format 1538
17.2.2.1 General 1538
17.2.2.2 Long PPDU format 1538
17.2.2.3 Short PPDU format 1538
17.2.3 PPDU field definitions 1539
17.2.3.1 General 1539
17.2.3.2 Long PLCP SYNC field 1539
17.2.3.3 Long PLCP SFD 1539
17.2.3.4 Long PLCP SIGNAL field 1539
17.2.3.5 Long PLCP SERVICE field 1540
17.2.3.6 Long PLCP LENGTH field 1540
17.2.3.7 PLCP CRC (CRC-16) field 1542
17.2.3.8 Long PLCP data modulation and modulation rate change 1544
17.2.3.9 Short PLCP synchronization (shortSYNC) 1544
17.2.3.10 Short PLCP SFD field (shortSFD) 1544
17.2.3.11 Short PLCP SIGNAL field (shortSIGNAL) 1545
17.2.3.12 Short PLCP SERVICE field (shortSERVICE) 1545
17.2.3.13 Short PLCP LENGTH field (shortLENGTH) 1545
17.2.3.14 Short CRC-16 field (shortCRC) 1545
17.2.3.15 Short PLCP data modulation and modulation rate change 1545
17.2.4 PLCP/High Rate PHY data scrambler and descrambler 1545
17.2.5 Transmit PLCP 1546
17.2.6 Receive PLCP 1548
17.3 High Rate PLME 1551
17.3.1 PLME_SAP sublayer management primitives 1551
17.3.2 High Rate PHY MIB 1551
17.3.3 DS PHY characteristics 1552
17.3.4 High Rate TXTIME calculation 1553
17.3.5 Vector descriptions 1553
17.4 High Rate PMD sublayer 1554
17.4.1 Scope and field of application 1554
17.4.2 Overview of service 1555
17.4.3 Overview of interactions 1555
17.4.4 Basic service and options 1555
17.4.4.1 General 1555
17.4.4.2 PMD_SAP peer-to-peer service primitives 1555
17.4.4.3 PMD_SAP sublayer-to-sublayer service primitives 1556
17.4.5 PMD_SAP detailed service specification 1556
17.4.5.1 Introduction 1556
17.4.5.2 PMD_DATA.request 1556
17.4.5.3 PMD_DATA.indication 1557

17.4.5.4 PMD_MODULATION.request ... 1557
17.4.5.5 PMD_PREAMBLE.request ... 1558
17.4.5.6 PMD_PREAMBLE.indication ... 1559
17.4.5.7 PMD_TXSTART.request ... 1559
17.4.5.8 PMD_TXEND.request ... 1560
17.4.5.9 PMD_ANTSEL.request ... 1560
17.4.5.10 PMD_TXPWRLVL.request ... 1560
17.4.5.11 PMD_RATE.request ... 1561
17.4.5.12 PMD_RSSI.indication ... 1562
17.4.5.13 PMD_SQ.indication ... 1562
17.4.5.14 PMD_CS.indication ... 1563
17.4.5.15 PMD_ED.indication ... 1564
17.4.5.16 PMD_ED.request ... 1564
17.4.5.17 PMD_RCPI.indication ... 1565
17.4.6 PMD operating specifications, general ... 1565
17.4.6.1 General ... 1565
17.4.6.2 Operating frequency range ... 1566
17.4.6.3 Channel Numbering of operating channels ... 1566
17.4.6.4 Modulation and channel data rates ... 1566
17.4.6.5 Spreading sequence and modulation for 1 Mb/s and 2 Mb/s ... 1567
17.4.6.6 Spreading sequences and modulation for CCK modulation at 5.5 Mb/s and 11 Mb/s ... 1567
17.4.6.7 DSSS/PBCC data modulation and modulation rate (optional) ... 1569
17.4.6.8 Channel Agility (optional) ... 1572
17.4.6.9 Transmit and receive in-band and out-of-band spurious emissions ... 1575
17.4.6.10 TX-to-RX turnaround time ... 1575
17.4.6.11 RX-to-TX turnaround time ... 1575
17.4.6.12 Slot time ... 1575
17.4.6.13 Channel switching/settling time ... 1575
17.4.6.14 Transmit and receive antenna port impedance ... 1575
17.4.7 PMD transmit specifications ... 1575
17.4.7.1 Introduction ... 1575
17.4.7.2 Transmit power levels ... 1575
17.4.7.3 Transmit power level control ... 1576
17.4.7.4 Transmit spectrum mask ... 1576
17.4.7.5 Transmit center frequency tolerance ... 1576
17.4.7.6 Chip clock frequency tolerance ... 1576
17.4.7.7 Transmit power-on and power-down ramp ... 1577
17.4.7.8 RF carrier suppression ... 1577
17.4.7.9 Transmit modulation accuracy ... 1578
17.4.7.10 Time of Departure accuracy ... 1580
17.4.8 PMD receiver specifications ... 1580
17.4.8.1 Introduction ... 1580
17.4.8.2 Receiver minimum input level sensitivity ... 1580
17.4.8.3 Receiver maximum input level ... 1580
17.4.8.4 Receiver adjacent channel rejection ... 1581
17.4.8.5 CCA ... 1581
17.4.8.6 Received Channel Power Indicator Measurement ... 1582

18. Orthogonal frequency division multiplexing (OFDM) PHY specification ... 1583

18.1 Introduction ... 1583
18.1.1 General ... 1583
18.1.2 Scope ... 1583

18.1.3 OFDM PHY functions ... 1583
18.1.3.1 General ... 1583
18.1.3.2 PLCP sublayer ... 1583
18.1.3.3 PMD sublayer ... 1584
18.1.3.4 PLME ... 1584
18.1.3.5 Service specification method ... 1584
18.2 OFDM PHY specific service parameter list ... 1584
18.2.1 Introduction ... 1584
18.2.2 TXVECTOR parameters ... 1584
18.2.2.1 General ... 1584
18.2.2.2 TXVECTOR LENGTH ... 1584
18.2.2.3 TXVECTOR DATARATE ... 1584
18.2.2.4 TXVECTOR SERVICE ... 1585
18.2.2.5 TXVECTOR TXPWR_LEVEL ... 1585
18.2.2.6 TIME_OF_DEPARTURE_REQUESTED ... 1585
18.2.3 RXVECTOR parameters ... 1585
18.2.3.1 General ... 1585
18.2.3.2 RXVECTOR LENGTH ... 1586
18.2.3.3 RXVECTOR RSSI ... 1586
18.2.3.4 DATARATE ... 1587
18.2.3.5 SERVICE ... 1587
18.2.3.6 RXVECTOR RCPI ... 1587
18.2.4 TXSTATUS parameters ... 1587
18.2.4.1 General ... 1587
18.2.4.2 TXSTATUS TIME_OF_DEPARTURE ... 1587
18.2.4.3 TXSTATUS TIME_OF_DEPARTURE_ClockRate ... 1588
18.3 OFDM PLCP sublayer ... 1588
18.3.1 Introduction ... 1588
18.3.2 PLCP frame format ... 1588
18.3.2.1 General ... 1588
18.3.2.2 Overview of the PPDU encoding process ... 1588
18.3.2.3 Modulation-dependent parameters ... 1590
18.3.2.4 Timing related parameters ... 1590
18.3.2.5 Mathematical conventions in the signal descriptions ... 1591
18.3.2.6 Discrete time implementation considerations ... 1593
18.3.3 PLCP preamble (SYNC) ... 1593
18.3.4 SIGNAL field ... 1595
18.3.4.1 General ... 1595
18.3.4.2 RATE field ... 1595
18.3.4.3 PLCP LENGTH field ... 1596
18.3.4.4 Parity (P), Reserved (R), and SIGNAL TAIL fields ... 1596
18.3.5 DATA field ... 1596
18.3.5.1 General ... 1596
18.3.5.2 SERVICE field ... 1596
18.3.5.3 PPDU TAIL field ... 1596
18.3.5.4 Pad bits (PAD) ... 1596
18.3.5.5 PLCP DATA scrambler and descrambler ... 1597
18.3.5.6 Convolutional encoder ... 1597
18.3.5.7 Data interleaving ... 1598
18.3.5.8 Subcarrier modulation mapping ... 1600
18.3.5.9 Pilot subcarriers ... 1603
18.3.5.10 OFDM modulation ... 1603
18.3.6 CCA ... 1604
18.3.7 PLCP data modulation and modulation rate change ... 1604

18.3.8 PMD operating specifications (general) ... 1605
18.3.8.1 General ... 1605
18.3.8.2 Outline description ... 1605
18.3.8.3 Regulatory requirements ... 1606
18.3.8.4 Operating channel frequencies ... 1606
18.3.8.5 Transmit and receive in-band and out-of-band spurious emissions ... 1607
18.3.8.6 TX RF delay ... 1607
18.3.8.7 Slot time ... 1607
18.3.8.8 Transmit and receive antenna port impedance ... 1607
18.3.9 PMD transmit specifications ... 1607
18.3.9.1 General ... 1607
18.3.9.2 Transmit power levels ... 1607
18.3.9.3 Transmit spectrum mask ... 1607
18.3.9.4 Transmission spurious ... 1608
18.3.9.5 Transmit center frequency tolerance ... 1609
18.3.9.6 Symbol clock frequency tolerance ... 1609
18.3.9.7 Modulation accuracy ... 1609
18.3.9.8 Transmit modulation accuracy test ... 1610
18.3.9.9 Time of Departure accuracy ... 1611
18.3.10 PMD receiver specifications ... 1612
18.3.10.1 Introduction ... 1612
18.3.10.2 Receiver minimum input sensitivity ... 1612
18.3.10.3 Adjacent channel rejection ... 1613
18.3.10.4 Nonadjacent channel rejection ... 1613
18.3.10.5 Receiver maximum input level ... 1614
18.3.10.6 CCA requirements ... 1614
18.3.10.7 Received Channel Power Indicator Measurement ... 1614
18.3.11 Transmit PLCP ... 1615
18.3.12 Receive PLCP ... 1618
18.4 OFDM PLME ... 1619
18.4.1 PLME_SAP sublayer management primitives ... 1619
18.4.2 OFDM PHY MIB ... 1620
18.4.3 OFDM TXTIME calculation ... 1622
18.4.4 OFDM PHY characteristics ... 1622
18.5 OFDM PMD sublayer ... 1624
18.5.1 Scope and field of application ... 1624
18.5.2 Overview of service ... 1624
18.5.3 Overview of interactions ... 1624
18.5.4 Basic service and options ... 1624
18.5.4.1 General ... 1624
18.5.4.2 PMD_SAP peer-to-peer service primitives ... 1624
18.5.4.3 PMD_SAP sublayer-to-sublayer service primitives ... 1625
18.5.4.4 PMD_SAP service primitive parameters ... 1625
18.5.5 PMD_SAP detailed service specification ... 1626
18.5.5.1 Introduction ... 1626
18.5.5.2 PMD_DATA.request ... 1626
18.5.5.3 PMD_DATA.indication ... 1626
18.5.5.4 PMD_TXSTART.request ... 1627
18.5.5.5 PMD_TXEND.request ... 1627
18.5.5.6 PMD_TXPWRLVL.request ... 1628
18.5.5.7 PMD_RATE.request ... 1628
18.5.5.8 PMD_RSSI.indication ... 1629
18.5.5.9 PMD_RCPI.indication ... 1629

19. Extended Rate PHY (ERP) specification ... 1631

19.1 Overview ... 1631
19.1.1 General ... 1631
19.1.2 Introduction ... 1631
19.1.3 Operational modes ... 1631
19.1.4 Scope ... 1632
19.1.5 ERP functions ... 1632
19.2 PHY-specific service parameter list ... 1633
19.3 Extended Rate PLCP sublayer ... 1635
19.3.1 Introduction ... 1635
19.3.2 PPDU format ... 1635
19.3.2.1 General ... 1635
19.3.2.2 Long preamble PPDU format ... 1636
19.3.2.3 Short preamble PPDU format ... 1638
19.3.2.4 ERP-OFDM PPDU format ... 1638
19.3.2.5 DSSS-OFDM long preamble PPDU format ... 1638
19.3.2.6 DSSS-OFDM PLCP length field calculation ... 1639
19.3.2.7 Short DSSS-OFDM PLCP PPDU format ... 1640
19.3.3 PLCP data modulation and rate change ... 1640
19.3.3.1 Long and short preamble formats ... 1640
19.3.3.2 ERP-PBCC 22 Mb/s and 33 Mb/s formats ... 1641
19.3.3.3 ERP-OFDM format ... 1643
19.3.3.4 Long and short DSSS-OFDM PLCP format ... 1643
19.3.4 PLCP transmit procedure ... 1644
19.3.5 CCA ... 1644
19.3.6 PLCP receive procedure ... 1644
19.4 ERP PMD operating specifications (general) ... 1645
19.4.1 Introduction ... 1645
19.4.2 Regulatory requirements ... 1645
19.4.3 Operating channel frequencies ... 1645
19.4.4 Transmit and receive in-band and out-of-band spurious emissions ... 1645
19.4.5 Slot time ... 1645
19.4.6 SIFS value ... 1645
19.4.7 CCA performance ... 1645
19.4.8 PMD transmit specifications ... 1646
19.4.8.1 General ... 1646
19.4.8.2 Transmit power levels ... 1646
19.4.8.3 Transmit center frequency tolerance ... 1646
19.4.8.4 Symbol clock frequency tolerance ... 1646
19.4.8.5 Time of Departure accuracy ... 1646
19.5 ERP operation specifications ... 1647
19.5.1 General ... 1647
19.5.2 Receiver minimum input level sensitivity ... 1647
19.5.3 Adjacent channel rejection ... 1647
19.5.4 Receive maximum input level capability ... 1647
19.5.5 Transmit spectral mask ... 1647
19.6 ERP-PBCC operation specifications ... 1647
19.6.1 General ... 1647
19.6.2 Receiver minimum input level sensitivity ... 1648
19.6.3 Receiver adjacent channel rejection ... 1648
19.7 DSSS-OFDM operation specifications ... 1648
19.7.1 General ... 1648
19.7.2 Overview ... 1648

19.7.3 Single carrier to multicarrier transition requirements ... 1648
19.7.3.1 General ... 1648
19.7.3.2 Spectral binding requirement ... 1649
19.7.3.3 Sample-power matching requirement ... 1655
19.7.3.4 Transition time alignment ... 1655
19.7.3.5 Single carrier termination ... 1657
19.7.3.6 Transition carrier frequency requirement ... 1657
19.7.3.7 Transition carrier phase requirement ... 1658
19.7.3.8 Transmit modulation accuracy requirement ... 1659
19.8 ERP PLME ... 1659
19.8.1 PLME SAP ... 1659
19.8.2 MIB ... 1659
19.8.3 TXTIME ... 1661
19.8.3.1 General ... 1661
19.8.3.2 ERP-OFDM TXTIME calculations ... 1661
19.8.3.3 ERP-PBCC TXTIME calculations ... 1662
19.8.3.4 DSSS-OFDM TXTIME calculations ... 1662
19.8.4 ERP-OFDM PLCP PSDU definition ... 1663
19.9 Extended rate PMD sublayer ... 1664
19.9.1 Scope and field of application ... 1664
19.9.2 Overview of service ... 1664
19.9.3 Overview of Interactions ... 1664
19.9.4 Basic service and options ... 1664
19.9.4.1 General ... 1664
19.9.4.2 PMD_SAP peer-to-peer service primitives ... 1664
19.9.4.3 PMD_SAP sublayer-to-sublayer service primitives ... 1665
19.9.4.4 PMD_SAP service primitive parameters ... 1665
19.9.5 PMD_SAP detailed service specification ... 1667
19.9.5.1 Introduction ... 1667
19.9.5.2 PMD_DATA.request ... 1667
19.9.5.3 PMD_DATA.indication ... 1667
19.9.5.4 PMD_MODULATION.request ... 1667
19.9.5.5 PMD_PREAMBLE.request ... 1667
19.9.5.6 PMD_TXSTART.request ... 1668
19.9.5.7 PMD_TXEND.request ... 1668
19.9.5.8 PMD_ANTSEL.request ... 1668
19.9.5.9 PMD_TXPRWLVL.request ... 1668
19.9.5.10 PMD_RATE.request ... 1668
19.9.5.11 PMD_RSSI.indication ... 1668
19.9.5.12 PMD_SQ.indication ... 1668
19.9.5.13 PMD_CS.indication ... 1668
19.9.5.14 PMD_ED.indication ... 1668
19.9.5.15 PMD_RCPI.indication ... 1668

20. High Throughput (HT) PHY specification ... 1669

20.1 Introduction ... 1669
20.1.1 Introduction to the HT PHY ... 1669
20.1.2 Scope ... 1669
20.1.3 HT PHY functions ... 1669
20.1.3.1 General ... 1669
20.1.3.2 HT PLCP sublayer ... 1670
20.1.3.3 HT PMD sublayer ... 1670
20.1.3.4 PHY management entity (PLME) ... 1670

20.1.3.5 Service specification method 1670
20.1.4 PPDU formats 1670
20.2 HT PHY service interface 1671
20.2.1 Introduction 1671
20.2.2 TXVECTOR and RXVECTOR parameters 1671
20.2.3 Effect of CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format 1678
20.2.4 Support for NON_HT formats 1679
20.2.5 TXSTATUS parameters 1681
20.3 HT PLCP sublayer 1681
20.3.1 Introduction 1681
20.3.2 PPDU format 1681
20.3.3 Transmitter block diagram 1683
20.3.4 Overview of the PPDU encoding process 1684
20.3.5 Modulation and coding scheme (MCS) 1688
20.3.6 Timing-related parameters 1689
20.3.7 Mathematical description of signals 1691
20.3.8 Transmission in the upper/lower 20 MHz of a 40 MHz channel 1693
20.3.9 HT preamble 1694
20.3.9.1 Introduction 1694
20.3.9.2 HT-mixed format preamble 1694
20.3.9.3 Non-HT portion of the HT-mixed format preamble 1694
20.3.9.4 HT portion of HT-mixed format preamble 1698
20.3.9.5 HT-greenfield format preamble 1707
20.3.10 Transmission of NON_HT format PPDUs with more than one antenna 1710
20.3.11 Data field 1710
20.3.11.1 General 1710
20.3.11.2 SERVICE field 1710
20.3.11.3 Scrambler 1710
20.3.11.4 Coding 1711
20.3.11.5 Encoder parsing operation for two BCC FEC encoders 1711
20.3.11.6 Binary convolutional coding and puncturing 1711
20.3.11.7 LDPC codes 1711
20.3.11.8 Data interleaver 1716
20.3.11.9 Constellation mapping 1718
20.3.11.10 Pilot subcarriers 1720
20.3.11.11 OFDM modulation 1722
20.3.11.12 Non-HT duplicate transmission 1726
20.3.12 Beamforming 1727
20.3.12.1 General 1727
20.3.12.2 Implicit feedback beamforming 1728
20.3.12.3 Explicit feedback beamforming 1730
20.3.13 HT Preamble format for sounding PPDUs 1735
20.3.13.1 General 1735
20.3.13.2 Sounding with a NDP 1735
20.3.13.3 Sounding PPDU for calibration 1736
20.3.13.4 Sounding PPDU for channel quality assessment 1736
20.3.14 Regulatory requirements 1737
20.3.15 Channel numbering and channelization 1737
20.3.15.1 General 1737
20.3.15.2 Channel allocation in the 2.4 GHz Band 1737
20.3.15.3 Channel allocation in the 5 GHz band 1738
20.3.15.4 40 MHz channelization 1738
20.3.16 Transmit and receive in-band and out-of-band spurious transmissions 1738

20.3.17 Transmitter RF delay ... 1738
20.3.18 Slot time ... 1738
20.3.19 Transmit and receive port impedance ... 1738
20.3.20 PMD transmit specification ... 1739
20.3.20.1 Transmit spectrum mask ... 1739
20.3.20.2 Spectral flatness ... 1741
20.3.20.3 Transmit power ... 1741
20.3.20.4 Transmit center frequency tolerance ... 1741
20.3.20.5 Packet alignment ... 1741
20.3.20.6 Symbol clock frequency tolerance ... 1742
20.3.20.7 Modulation accuracy ... 1742
20.3.20.8 Time of Departure accuracy ... 1744
20.3.21 HT PMD receiver specification ... 1744
20.3.21.1 Receiver minimum input sensitivity ... 1744
20.3.21.2 Adjacent channel rejection ... 1745
20.3.21.3 Nonadjacent channel rejection ... 1745
20.3.21.4 Receiver maximum input level ... 1746
20.3.21.5 CCA sensitivity ... 1746
20.3.21.6 Received channel power indicator (RCPI) measurement ... 1747
20.3.21.7 Reduced interframe space (RIFS) ... 1747
20.3.22 PLCP transmit procedure ... 1748
20.3.23 PLCP receive procedure ... 1750
20.4 HT PLME ... 1755
20.4.1 PLME_SAP sublayer management primitives ... 1755
20.4.2 PHY MIB ... 1756
20.4.3 TXTIME calculation ... 1760
20.4.4 PHY characteristics ... 1761
20.5 HT PMD sublayer ... 1762
20.5.1 Scope and field of application ... 1762
20.5.2 Overview of service ... 1762
20.5.3 Overview of interactions ... 1763
20.5.4 Basic service and options ... 1763
20.5.4.1 Status of service primitives ... 1763
20.5.4.2 PMD_SAP peer-to-peer service primitives ... 1763
20.5.4.3 PMD_SAP sublayer-to-sublayer service primitives ... 1763
20.5.4.4 PMD_SAP service primitive parameters ... 1764
20.5.5 PMD_SAP detailed service specification ... 1765
20.5.5.1 Introduction to PMD_SAP service specification ... 1765
20.5.5.2 PMD_DATA.request ... 1765
20.5.5.3 PMD_DATA.indication ... 1765
20.5.5.4 PMD_TXSTART.request ... 1766
20.5.5.5 PMD_TXEND.request ... 1766
20.5.5.6 PMD_TXEND.confirm ... 1767
20.5.5.7 PMD_TXPWRLVL.request ... 1767
20.5.5.8 PMD_RSSI.indication ... 1768
20.5.5.9 PMD_RCPI.indication ... 1768
20.5.5.10 PMD_TX_PARAMETERS.request ... 1769
20.5.5.11 PMD_CBW_OFFSET.indication ... 1769
20.5.5.12 PMD_CHAN_MAT.indication ... 1770
20.5.5.13 PMD_FORMAT.indication ... 1770
20.6 Parameters for HT MCSs ... 1771

Annex A (informative) Bibliography ... 1781

Annex B (normative) Protocol Implementation Conformance Statement (PICS) proforma ... 1785

B.1 Introduction ... 1785
B.2 Abbreviations and special symbols ... 1785
B.2.1 Symbols for Status column ... 1785
B.2.2 General abbreviations for Item and Support columns ... 1785
B.3 Instructions for completing the PICS proforma ... 1786
B.3.1 General structure of the PICS proforma ... 1786
B.3.2 Additional information ... 1787
B.3.3 Exception information ... 1787
B.3.4 Conditional status ... 1787
B.4 PICS proforma—IEEE Std 802.11-2012 ... 1788
B.4.1 Implementation identification ... 1788
B.4.2 Protocol summary ... 1789
B.4.3 IUT configuration ... 1789
B.4.4 MAC protocol ... 1790
B.4.5 Frequency hopping (FH) PHY functions ... 1800
B.4.6 Direct sequence PHY functions ... 1803
B.4.7 IR baseband PHY functions ... 1806
B.4.8 OFDM PHY functions ... 1809
B.4.9 High Rate, direct sequence PHY functions ... 1819
B.4.10 Regulatory Domain Extensions ... 1823
B.4.11 ERP functions ... 1824
B.4.12 Spectrum management extensions ... 1828
B.4.13 Operating Classes extensions ... 1830
B.4.14 QoS base functionality ... 1830
B.4.15 QoS enhanced distributed channel access (EDCA) ... 1831
B.4.16 QoS hybrid coordination function (HCF) controlled channel access (HCCA) ... 1832
B.4.17 Radio Management extensions ... 1832
B.4.18 DSE functions ... 1837
B.4.19 High-throughput (HT) features ... 1838
B.4.20 Tunneled direct-link setup extensions ... 1845
B.4.21 WNM extensions ... 1846
B.4.22 Interworking (IW) with external networks extensions ... 1849
B.4.23 Mesh protocol capabilities ... 1850

Annex C (normative) ASN.1 encoding of the MAC and PHY MIB ... 1855

C.1 General ... 1855
C.2 Guidelines for 802.11 MIB Authors/Editors ... 1855
C.3 MIB Detail ... 1855

Annex D (normative) Regulatory references ... 2287

D.1 External regulatory references ... 2287
D.2 Radio performance specifications ... 2289
D.2.1 Transmit and receive in-band and out-of-band spurious emissions ... 2289
D.2.2 Transmit power levels ... 2289
D.2.3 Transmit spectrum mask ... 2289
D.2.4 Transmit Mask M ... 2291
D.2.5 CCA-ED threshold ... 2292

Annex E (normative) Country elements and operating classes 2293

E.1 Country information and operating classes 2293
E.2 Band-specific operating requirements 2302
E.2.1 General 2302
E.2.2 3650–3700 MHz in the United States 2302
E.2.3 5.9 GHz band in the United States (5.850–5.925 GHz) 2303
E.2.4 5.9 GHz band in Europe (5.855–5.925 GHz) 2303

Annex F (normative) HT LDPC matrix definitions 2304

Annex G (normative) Frame exchange sequences 2307

G.1 General 2307
G.2 Basic sequences 2309
G.3 EDCA and HCCA sequences 2310
G.4 HT sequences 2312

Annex H (normative) Usage of Ethertype 89-0d 2320

Annex I (informative) Hopping sequences 2321

Annex J (informative) Formal description of a subset of MAC operation 2334

J.1 Status of this annex 2334
J.2 Overview 2334
J.3 Introduction to the MAC formal description 2337
J.3.1 Fundamental assumptions 2337
J.3.2 Notation conventions 2337
J.3.3 Modeling techniques 2338
J.4 Data type and operator definitions for the MAC state machines 2339
J.5 State machines for MAC STAs 2387
J.6 State machines for MAC AP 2464

Annex K (informative) High Rate PHY/FH interoperability 2535

K.1 Status of this Annex 2535
K.2 General 2535

Annex L (informative) Examples of encoding a frame for OFDM PHYs 2536

L.1 Example 1 - BCC encoding 2536
L.1.1 Introduction 2536
L.1.2 The message for the BCC example 2537
L.1.3 Generation of the preamble 2538
L.1.4 Generation of the SIGNAL field 2543
L.1.5 Generating the DATA bits for the BCC example 2547
L.1.6 Generating the first DATA symbol for the BCC example 2551
L.1.7 Generating the additional DATA symbols 2556
L.1.8 The entire packet for the BCC example 2556
L.2 Generating encoded DATA bits—LDPC example 1 2565
L.2.1 The message for LDPC example 1 2565
L.2.2 Prepending the SERVICE field for LDPC example 1 2566
L.2.3 Scrambling LDPC example 1 2568

L.2.4 Inserting shortening bits for LDPC example 1 ... 2569
L.2.5 Encoding data for LDPC example 1 ... 2571
L.2.6 Removing shortening bits and puncturing for LDPC example 1 ... 2574
L.3 Generating encoded DATA bits—LDPC example 2 ... 2576
L.3.1 The message for LDPC example 2 ... 2576
L.3.2 Prepending the SERVICE field for LDPC example 2 ... 2578
L.3.3 Scrambling LDPC example 2 ... 2579
L.3.4 Inserting the shortening bits for LDPC example 2 ... 2581
L.3.5 Encoding the data for LDPC example 2 ... 2583
L.3.6 Removing shortening bits and repetition for LDPC example 2 ... 2587

Annex M (informative) RSNA reference implementations and test vectors ... 2592

M.1 TKIP temporal key mixing function reference implementation and test vector ... 2592
M.1.1 TKIP temporal key mixing function reference implementation ... 2592
M.1.2 Test vectors ... 2602
M.2 Michael reference implementation and test vectors ... 2604
M.2.1 Michael test vectors ... 2604
M.2.2 Sample code for Michael ... 2605
M.3 PRF reference implementation and test vectors ... 2612
M.3.1 PRF reference code ... 2612
M.3.2 PRF test vectors ... 2613
M.4 Suggested pass-phrase-to-PSK mapping ... 2613
M.4.1 Introduction ... 2613
M.4.2 Reference implementation ... 2614
M.4.3 Test vectors ... 2616
M.5 Suggestions for random number generation ... 2616
M.5.1 General ... 2616
M.5.2 Software sampling ... 2616
M.5.3 Hardware-assisted solution ... 2617
M.6 Additional test vectors ... 2618
M.6.1 Notation ... 2618
M.6.2 WEP cryptographic encapsulation ... 2619
M.6.3 TKIP test vector ... 2620
M.6.4 CCMP test vector ... 2620
M.6.5 PRF test vectors ... 2621
M.7 Key hierarchy test vectors for pairwise keys ... 2623
M.7.1 General ... 2623
M.7.2 CCMP pairwise key derivation ... 2623
M.7.3 TKIP pairwise key derivation ... 2624
M.8 Test vectors for AES-128-CMAC ... 2624
M.9 Management frame protection test vectors ... 2624
M.9.1 BIP with broadcast Deauthentication frame ... 2624
M.9.2 CCMP with unicast Deauthentication frame ... 2625
M.10 SAE test vector ... 2626

Annex N (informative) Admission control ... 2628

N.1 Example use of TSPEC for admission control ... 2628
N.2 Recommended practices for contention-based admission control ... 2629
N.2.1 Use of ACM (admission control mandatory) subfield ... 2629
N.2.2 Deriving medium time ... 2629
N.3 Guidelines and reference design for sample scheduler and admission control unit ... 2630
N.3.1 Guidelines for deriving service schedule parameters ... 2630

N.3.2 TSPEC construction 2630
N.3.3 Reference design for sample scheduler and admission control unit 2632

Annex O (informative) An example of encoding a TIM virtual bit map 2636

O.1 Introduction 2636
O.2 Examples 2636
O.3 Sample C code 2639

Annex P (informative) Integration function 2646

P.1 Introduction 2646
P.2 Ethernet V2.0/IEEE 802.3 LAN integration function 2646
P.3 Example 2646
P.4 Integration service versus bridging 2648

Annex Q (informative) AP functional description 2649

Q.1 Introduction 2649
Q.2 Terminology 2649
Q.3 Primary ACM_STA functions 2653
Q.4 Primary AP functions 2653
Q.5 Primary DS functions 2655
Q.6 Primary portal function 2655
Q.7 AU example 2655

Annex R (informative) DS SAP specification 2656

R.1 Introduction 2656
R.2 SAP primitives 2657
R.2.1 General 2657
R.2.2 MSDU transfer 2657
R.2.3 Mapping updates 2658

Annex S (informative) Additional HT information 2660

S.1 Waveform generator tool 2660
S.2 A-MPDU deaggregation 2660
S.3 Example of an RD exchange sequence 2662
S.4 Illustration of determination of NDP addresses 2663
S.5 20/40 MHz BSS establishment and maintenance 2664
S.5.1 Signaling 20/40 MHz BSS capability and operation 2664
S.5.2 Establishing a 20/40 MHz BSS 2664
S.5.3 Monitoring channels for other BSS operation 2665

Annex T (informative) Location and Time Difference accuracy test 2667

T.1 Location via Time Difference of arrival 2667
T.2 Time Difference of departure accuracy test 2667

Annex U (informative) Example use of the Destination URI for Event and Diagnostic Reports 2670

U.1 Destination URI payload 2670
U.2 Use of HTTP (or HTTPS) for Destination URI of Event and Diagnostic Reports 2670

Annex V (informative) Interworking with external networks 2672

V.1 General 2672
V.2 Network discovery and selection 2672
V.2.1 General 2672
V.2.2 Airport 2672
V.2.3 Shopping 2673
V.2.4 Sales meeting 2674
V.2.5 Museum 2674
V.2.6 Emergency call 2675
V.2.7 Emergency alert 2676
V.3 QoS mapping guidelines for interworking with external networks 2676
V.3.1 General 2676
V.3.2 Determination of the mapping for a STA 2677
V.3.3 Example of QoS mapping from different networks 2677
V.4 Interworking and SSPN interface support 2679
V.4.1 General 2679
V.4.2 SSPN interface parameters 2680
V.5 Interworking with external networks and emergency call support 2683
V.5.1 General 2683
V.5.2 Background on emergency call support over IEEE 802.11 infrastructure 2684
V.5.3 System aspects for emergency call support 2684
V.5.4 Description of the Expedited Bandwidth Request element 2686
V.5.5 Access to emergency services in an RSN 2686
V.6 Peer information 2687

Annex W (informative) Mesh BSS operation 2688

W.1 Clarification of Mesh Data frame format 2688
W.2 Operational considerations for interworking 2688
W.2.1 Formation and maintenance of the IEEE 802.1D spanning tree 2688
W.3 Power save parameters selection 2688
W.3.1 General 2688
W.3.2 Selecting the mesh power mode based on traffic load 2689
W.3.3 Scanning of mesh BSSs 2689
W.3.4 Default parameters 2689
W.3.5 MSDU forwarding in an MBSS containing mesh STAs in light or deep sleep mode 2690
W.3.6 Synchronization maintenance of mesh STAs in deep sleep mode 2690
W.4 SIV key wrapping test vector 2690
W.5 Airtime link metric usage example 2692
W.6 Generation of proactive PREPs in proactive PREQ mechanism of HWMP 2692
W.6.1 General 2692
W.6.2 Additions to forwarding information 2693
W.6.3 Actions when sending data frames as source mesh STA 2693
W.6.4 Actions on receipt of proactive PREQ 2693
W.6.5 Generation of proactive PREPs 2693
W.7 Generation of PREQs in proactive RANN mechanism of HWMP 2694
W.7.1 General 2694
W.7.2 Additions to forwarding information 2694
W.7.3 Actions when sending data frames as source mesh STA 2694
W.7.4 Actions on receipt of proactive RANN 2694
W.7.5 Actions on receipt of PREP 2695

Tables

Table 6-1—Supported TS management primitives 173
Table 6-2—Reason codes for network down 346
Table 6-3—Reason codes for ESS link down 347
Table 6-4—ESS description 349
Table 6-5—Trigger support values 349
Table 6-6—Event Capability Set 353
Table 6-7—ESS Link Parameter Set 354
Table 7-1—PHY-SAP peer-to-peer service primitives 369
Table 7-2—PHY-SAP sublayer-to-sublayer service primitives 369
Table 7-3—PHY-SAP service primitive parameters 369
Table 7-4—Vector descriptions 370
Table 8-1—Valid type and subtype combinations 382
Table 8-2—To/From DS combinations in data frames 384
Table 8-3—Duration/ID field encoding 387
Table 8-4—QoS Control field 389
Table 8-5—TID subfield 390
Table 8-6—Ack Policy subfield in QoS Control field of QoS data frames 391
Table 8-7—Subfields of Link Adaptation Control subfield 395
Table 8-8—Subfields of the MAI subfield 395
Table 8-9—ASEL Command and ASEL Data subfields 396
Table 8-10—Calibration control subfields 397
Table 8-11—CSI/Steering subfield values 397
Table 8-12—AC Constraint subfield values 397
Table 8-13—RDG/More PPDU subfield values 398
Table 8-14—Valid values for the Address Extension Mode 399
Table 8-16—BlockAckReq frame variant encoding 408
Table 8-15—BAR Ack Policy subfield 408
Table 8-17—BA Ack Policy subfield 410
Table 8-18—BlockAck frame variant encoding 411
Table 8-19—Address field contents 414
Table 8-20—Beacon frame body 419
Table 8-21—Disassociation frame body 423
Table 8-22—Association Request frame body 423
Table 8-23—Association Response frame body 425
Table 8-24—Reassociation Request frame body 426
Table 8-25—Reassociation Response frame body 428
Table 8-26—Probe Request frame body 429
Table 8-27—Probe Response frame body 430
Table 8-28—Authentication frame body 434
Table 8-29—Presence of fields and elements in Authentication frames 435
Table 8-30—Deauthentication frame body 436
Table 8-31—Action frame body 436
Table 8-32—Action No Ack frame body 436
Table 8-33—Timing Advertisement frame body 437
Table 8-34—Non-AP STA usage of QoS, CF-Pollable, and CF-Poll Request 439
Table 8-35—AP usage of QoS, CF-Pollable, and CF-Poll Request 439
Table 8-36—Reason codes 442
Table 8-37—Status codes 446
Table 8-38—Category values 450
Table 8-39—Settings of the Max SP Length subfield 453
Table 8-40—Settings of the Channel Width field 455
Table 8-41—Settings of the PCO Phase Control field 456

Table 8-42—Subfields of the MIMO Control field ... 458
Table 8-43—CSI Report field (20 MHz) ... 459
Table 8-44—CSI Report field (40 MHz) ... 460
Table 8-45—Number of matrices and carrier grouping ... 461
Table 8-47—Noncompressed Beamforming Report field (40 MHz) ... 462
Table 8-46—Noncompressed Beamforming Report field (20 MHz) ... 462
Table 8-48—Order of angles in the Compressed Beamforming Report field ... 463
Table 8-49—Quantization of angles ... 464
Table 8-50—Compressed Beamforming Report field (20 MHz) ... 464
Table 8-51—Compressed Beamforming Report field (40 MHz) ... 465
Table 8-52—Venue group codes and descriptions ... 469
Table 8-53—Venue type assignments ... 469
Table 8-54—Element IDs ... 474
Table 8-55—BSS membership selector value encoding ... 479
Table 8-56—Coverage Class field parameters ... 484
Table 8-57—Values of the Secondary Channel Offset field ... 492
Table 8-58—Summary of use of Enable, Request, and Report bits ... 493
Table 8-59—Measurement Type definitions for measurement requests ... 494
Table 8-60—Optional subelement IDs for Channel Load Request ... 496
Table 8-61—Reporting Condition for Channel Load Report ... 497
Table 8-62—Optional subelement IDs for Noise Histogram Request ... 498
Table 8-63—Reporting Condition for Noise Histogram Report ... 498
Table 8-64—Measurement Mode definitions for Beacon Request element ... 499
Table 8-65—Optional subelement IDs for Beacon Request ... 500
Table 8-66—Reporting Condition for Beacon Report ... 501
Table 8-67—Reporting Detail values ... 502
Table 8-68—Optional subelement IDs for frame request ... 503
Table 8-69—Group Identity for a STA Statistics Request ... 504
Table 8-70—Optional subelement IDs for STA Statistics Request ... 504
Table 8-71—Location subject definition ... 508
Table 8-72—Optional subelement IDs for LCI Request ... 509
Table 8-73—Optional subelement IDs for Transmit Stream/Category Measurement Request ... 511
Table 8-74—Delayed MSDU Range Definitions ... 513
Table 8-75—Optional subelement IDs for measurement pause request ... 514
Table 8-77—Civic Location Type ... 516
Table 8-76—Optional subelement IDs for STA Multicast Diagnostics Request ... 516
Table 8-79—Optional subelement IDs for Location Civic Request ... 517
Table 8-78—Location Service Interval Units ... 517
Table 8-80—Optional subelement IDs for Location Identifier Request ... 518
Table 8-81—Measurement Type definitions for measurement reports ... 520
Table 8-82—RPI definitions for an RPI histogram report ... 523
Table 8-83—Optional subelement IDs for Channel Load Report ... 524
Table 8-84—IPI Definitions for a Noise Histogram Report ... 525
Table 8-85—Optional subelement IDs for Noise Histogram Report ... 525
Table 8-86—Optional subelement IDs for Beacon Report ... 527
Table 8-87—Optional subelement IDs for Frame Report ... 528
Table 8-88—Group Identity for a STA Statistics Report ... 530
Table 8-89—Optional subelement IDs for STA Statistics Report ... 537
Table 8-90—Optional subelement IDs for Location Configuration Information Report ... 540
Table 8-91—Delay definitions for a Transmit Stream/Category Measurement Report for a Bin 0 Range field value of 10 TU ... 543
Table 8-92—Optional subelement IDs for Transmit Stream/Category Measurement Report ... 544
Table 8-94—Summary of fields used in the STA Multicast Diagnostics Report ... 546
Table 8-93—Optional subelement IDs for Multicast Diagnostics Report ... 546

Table 8-95—Optional subelement IDs for Location Civic Report 547
Table 8-96—Location Shape IDs 548
Table 8-97—Map Types 552
Table 8-98—Optional subelement IDs for Location Identifier Report 553
Table 8-99—Cipher suite selectors 557
Table 8-100—Cipher suite usage 558
Table 8-101—AKM suite selectors 558
Table 8-102—PTKSA/GTKSA/STKSA replay counters usage 560
Table 8-103—Capabilities field 562
Table 8-104—ACI-to-AC coding 568
Table 8-106—Default EDCA parameter set for STA operation if dot11OCBActivated is true 569
Table 8-105—Default EDCA Parameter Set element parameter values if dot11OCBActivated is false 569
Table 8-107—Direction subfield encoding 570
Table 8-108—Access Policy subfield 570
Table 8-109—TS Info Ack Policy subfield encoding 571
Table 8-110—Setting of Schedule subfield 571
Table 8-111—Frame classifier type 574
Table 8-112—Classifier Parameters for Classifier Type 4 576
Table 8-113—Encoding of Processing subfield 579
Table 8-114—Reachability field 581
Table 8-115—Optional subelement IDs for neighbor report 583
Table 8-116—Preference field values 584
Table 8-118—Available Admission Capacity Bitmask definition 589
Table 8-117—Optional subelement IDs for Measurement Pilot Transmission 589
Table 8-119—RM Enabled Capabilities definition 592
Table 8-120—Optional subelement IDs for Multiple BSSID 595
Table 8-121—Subelement IDs 597
Table 8-122—Timeout Interval Type field value 599
Table 8-123—Resource type code in RIC Descriptor element 600
Table 8-124—Subfields of the HT Capabilities Info field 605
Table 8-125—Subfields of the A-MPDU Parameters field 607
Table 8-126—Transmit MCS Set 608
Table 8-127—Subfields of the HT Extended Capabilities field 609
Table 8-128—Subfields of the Transmit Beamforming Capabilities field 610
Table 8-129—ASEL Capability field subfields 613
Table 8-130—HT Operation element fields and subfields 614
Table 8-131—Encoding of the Timing Capabilities field 620
Table 8-132—Time Value field format when Timing Capabilities is 2 621
Table 8-133—Event Type definitions for event requests and reports 624
Table 8-134—Transition Event Request subelement 625
Table 8-135—RSNA Event Request subelement 627
Table 8-136—Peer-to-Peer Link Event Request subelement 629
Table 8-137—Event Report Status 631
Table 8-138—Transition and Transition Query reasons 632
Table 8-139—Peer Status definitions 635
Table 8-140—Diagnostic Request/Report Type definitions 636
Table 8-141—Association Diagnostic request contents 637
Table 8-142—IEEE 802.1X Authentication Diagnostic request contents 637
Table 8-143—Diagnostic Information subelement ID values 638
Table 8-144—Credentials values 639
Table 8-146—Device Type definitions 641
Table 8-145—Collocated Radio Type 641
Table 8-147—Power Save Mode definition 644
Table 8-148—Tx Power Modes 646

Table 8-149—Manufacturer Information STA Report contents 647
Table 8-150—Configuration Profile report contents 648
Table 8-151—Association Diagnostic report contents 648
Table 8-152—IEEE 802.1X Authentication Diagnostic report contents 649
Table 8-153—Location subelements 649
Table 8-154—Report Interval Units field 651
Table 8-155—Motion Indicator field 654
Table 8-156—Speed Units 655
Table 8-157—Indication Parameter values 657
Table 8-158—Request subelements 660
Table 8-159—Status subelements 661
Table 8-160—FMS Element Status and TFS Response Status definition 662
Table 8-161—QoS Traffic Capability Bitmask/Flags definition 664
Table 8-162—TFS Action Code field values 666
Table 8-163—TFS Request subelements 666
Table 8-164—Status subelements 668
Table 8-165—Action Type definitions 669
Table 8-166—WNM-Sleep Mode Response Status definition 669
Table 8-167—Status field values 671
Table 8-168—Usage Mode definitions 673
Table 8-169—Request Type definitions 675
Table 8-170—Optional Subelement IDs for DMS Descriptor 676
Table 8-171—Response Type field values 677
Table 8-172—Optional Subelement IDs for DMS Status 678
Table 8-173—Optional Subelement IDs for U-APSD Coexistence 679
Table 8-174—Access network type 680
Table 8-175—Advertisement protocol ID definitions 683
Table 8-176—Precedence Level field description 684
Table 8-177—Active Path Selection Protocol Identifier field values 687
Table 8-178—Active Path Selection Metric Identifier field values 687
Table 8-179—Congestion Control Mode Identifier field values 688
Table 8-180—Synchronization Method Identifier field values 688
Table 8-181—Authentication Protocol Identifier field values 689
Table 8-182—Mesh Peering Protocol Identifier field values 692
Table 8-183—MCCA Reply Code field values 698
Table 8-184—ANQP-element definitions 712
Table 8-185—Network Authentication Type Indicator definitions 716
Table 8-186—IPv6 Address field values 718
Table 8-187— IPv4 Address field values 719
Table 8-188—Authentication Parameter types 721
Table 8-190—Vendor Specific Authentication Parameters 722
Table 8-189—Authentication Parameter format for the Expanded EAP method 722
Table 8-191—Spectrum Management Action field values 726
Table 8-192—QoS Action field values 729
Table 8-194—ADDTS Response frame Action field format 730
Table 8-193—ADDTS Request frame Action field format 730
Table 8-195—DELTS frame Action field format 731
Table 8-196—Schedule frame Action field format 732
Table 8-197—QoS Map configure frame body 732
Table 8-198—DLS Action field values 733
Table 8-199—DLS Request frame Action field format 733
Table 8-200—DLS Response frame Action field format 734
Table 8-201—DLS Teardown frame Action field format 735
Table 8-202—Block Ack Action field values 735

Table 8-203—ADDBA Request frame Action field format ... 736
Table 8-204—ADDBA Response frame Action field format ... 736
Table 8-205—DELBA frame Action field format ... 737
Table 8-206—Radio Measurement Action field values ... 738
Table 8-207—Optional subelement IDs for Link Measurement Request frame ... 740
Table 8-208—Optional subelement IDs for Link Measurement Report frame ... 741
Table 8-209—Optional subelement IDs for Neighbor Report Request frame ... 742
Table 8-210—Public Action field values ... 743
Table 8-211—20/40 BSS Coexistence Management frame Action field format ... 744
Table 8-213—Reason Result Code field values ... 746
Table 8-212—Optional subelement IDs for Measurement Pilot frame ... 746
Table 8-214—Reason Result Code field values ... 747
Table 8-215—Reason Result Code field values ... 751
Table 8-216—GAS Initial Request frame body format ... 752
Table 8-217—GAS Initial Response frame body format ... 753
Table 8-218—GAS Comeback Request frame body format ... 754
Table 8-219—GAS Comeback Response frame body format ... 755
Table 8-220—Information for TDLS Discovery Response frame ... 756
Table 8-221—Location Parameters Element field for Location Track Notification frame ... 757
Table 8-222—FT Action field values ... 758
Table 8-223—FT Request frame body ... 759
Table 8-224—FT Response frame body ... 760
Table 8-225—FT Confirm frame body ... 760
Table 8-226—FT Ack frame body ... 761
Table 8-227—SA Query Action field values ... 762
Table 8-228—Public Action field values defined for Protected Dual of Public Action frames ... 763
Table 8-229—HT Action field values ... 763
Table 8-230—Notify Channel Width frame Action field format ... 764
Table 8-232—PSMP frame Action field format ... 765
Table 8-231—SM Power Save frame Action field format ... 765
Table 8-234—CSI frame Action field format ... 766
Table 8-235—Noncompressed Beamforming frame Action field format ... 766
Table 8-233—Set PCO Phase frame Action field format ... 766
Table 8-236—Compressed Beamforming frame Action field format ... 767
Table 8-237—Antenna Selection Indices Feedback frame Action field format ... 767
Table 8-238—TDLS Action field values ... 768
Table 8-239—Information for TDLS Setup Request Action field ... 768
Table 8-240—Information for TDLS Setup Response Action field ... 770
Table 8-241—Information for TDLS Setup Confirm Action field ... 771
Table 8-242—Information for TDLS Teardown Action field ... 772
Table 8-243—Information for TDLS Peer Traffic Indication Action field ... 772
Table 8-244—Information for TDLS Channel Switch Request Action field ... 773
Table 8-245—Information for TDLS Channel Switch Response Action field ... 773
Table 8-246—Information for TDLS Peer PSM Request Action field ... 774
Table 8-247—Information for TDLS Peer PSM Response Action field ... 774
Table 8-248—Information for TDLS Peer Traffic Response Action field ... 775
Table 8-249—Information for TDLS Discovery Request Action field ... 775
Table 8-250—WNM Action field values ... 776
Table 8-251—Location Parameters Element field for Location Configuration Request frame ... 779
Table 8-252—Location Parameters Element field for Location Configuration Response frame ... 780
Table 8-253—Status code definitions ... 784
Table 8-254—WNM-Sleep Mode subelement IDs ... 789
Table 8-255—QoS Traffic Capability Flags definition ... 792
Table 8-256—WNM-Notification type ... 795

Table 8-257—Optional subelement IDs for WNM-Notification Request 795
Table 8-258—WNM-Notification Response Status 796
Table 8-260—Unprotected WNM Action field values 797
Table 8-259—Optional subelement IDs for WNM-Notification Response 797
Table 8-261—Self-protected Action field values 799
Table 8-262—Mesh Peering Open frame Action field format 800
Table 8-263—Mesh Peering Confirm frame Action field format 801
Table 8-265—Mesh Group Key Inform frame Action field format 803
Table 8-264—Mesh Peering Close frame Action field format 803
Table 8-266—Mesh Group Key Acknowledge frame Action field format 804
Table 8-268—Mesh Link Metric Report frame Action field format 805
Table 8-267—Mesh Action field values 805
Table 8-269—HWMP Mesh Path Selection frame Action field format 806
Table 8-270—Gate Announcement frame Action field format 806
Table 8-271—Congestion Control Notification frame Action field format 807
Table 8-272—MCCA Setup Request frame Action field format 807
Table 8-273—MCCA Setup Reply frame Action field format 808
Table 8-274—MCCA Advertisement Request frame Action field format 808
Table 8-276—MCCA Teardown frame Action field format 809
Table 8-275—MCCA Advertisement frame Action field format 809
Table 8-278—TBTT Adjustment Response frame Action field format 810
Table 8-277—TBTT Adjustment Request frame Action field format 810
Table 8-279—Multihop Action field values 811
Table 8-280—Proxy Update frame Action field format 811
Table 8-281—Proxy Update Confirmation frame Action field format 812
Table 8-282— MPDU delimiter fields 813
Table 8-283—A-MPDU Contexts 815
Table 8-284—A-MPDU contents in the data enabled immediate response context 815
Table 8-285—A-MPDU contents in the data enabled no immediate response context 816
Table 8-287—A-MPDU contents MPDUs in the control response context 817
Table 8-286—A-MPDU contents in the PSMP context 817
Table 9-1—UP-to-AC mappings 820
Table 9-2—Dual CTS rules 831
Table 9-3—CH_BANDWIDTH control frame response mapping 862
Table 9-4—Modulation classes 863
Table 9-5—Non-HT reference rate 864
Table 9-6—HCC family – N = 11; Family indices (SEQ) 1 to 10 870
Table 9-8—EHCC family – Code length = 8, N = 11; Family indices (SEQ) 1 to 8 871
Table 9-7—EHCC family – Code length = 9, N = 11; Family Indices (SEQ) 1 to 9 871
Table 9-9—Protection requirements for HT Protection field values nonmember protection mode and non-HT mixed mode 921
Table 9-10—Applicable HT protection mechanisms 922
Table 9-11—STA type requirements for transmit beamforming with implicit feedback 946
Table 9-12—Transmit beamforming support required with implicit feedback 947
Table 9-14—Rules for beamformee immediate feedback transmission responding to NDP sounding 956
Table 9-13—Rules for beamformee immediate feedback transmission responding to non-NDP sounding 956
Table 9-15—Valid address field usage for Mesh Data and Multihop Action frames 965
Table 10-1—Power Management modes 985
Table 10-2—Types of Block Ack agreement based on capabilities and ADDBA conditions 1035
Table 10-3—ReasonCode values for DLS teardown 1042
Table 10-4—Allowed measurement requests 1049
Table 10-5—Measurement Duration 1059
Table 10-6—Allowed measurement requests 1061

Table 10-7—Measurement Pilot Activated definition 1080
Table 10-8—DSE STA attributes 1085
Table 10-9—A-MSDU STA behavior for RSN associations 1108
Table 10-10—ANQP usage 1153
Table 10-11—ESR and UESA field settings 1159
Table 11-1—AAD length 1208
Table 11-2—Robust management frame selection in an ESS 1223
Table 11-3—Robust management frame selection in an IBSS 1225
Table 11-4—Cipher suite key lengths 1247
Table 11-5—Key RSC field 1248
Table 11-6—KDE 1249
Table 11-7—MUI values 1251
Table 11-8—SMK error types 1251
Table 11-9—Integrity and key-wrap algorithms 1253
Table 12-1—FT authentication elements 1328
Table 12-2—Remote Request/Response Payload format 1345
Table 12-3—Resource types and resource descriptor definitions 1346
Table 13-1—State variables for mesh STAs 1357
Table 13-2—MPM finite state machine 1364
Table 13-3—AMPE finite state machine 1375
Table 13-4—Airtime cost constants 1382
Table 13-5—Parameters of the airtime link metric for extensible path selection framework 1382
Table 13-6—Precursor and next hop examples (forward path) 1385
Table 13-7—Precursor and next hop examples (reverse path) 1385
Table 13-8—Parameters of HWMP for extensible path selection framework 1387
Table 13-9—Data for creation and update of forwarding information due to PREQ and PREP 1391
Table 13-10—Contents of a PREQ element in Case A 1393
Table 13-11—Contents of a PREQ element in Case B 1394
Table 13-12—Contents of a PREQ element in Case C 1395
Table 13-13—Contents of a PREQ element in Case D 1396
Table 13-14—Contents of a PREQ element in Case E1 1397
Table 13-15—Contents of a PREQ element in Case E2 1398
Table 13-16—Contents of a PREQ element in Case E3 1399
Table 13-17—Contents of a PREP element in Case A 1402
Table 13-18—Contents of a PREP element in Case B 1403
Table 13-19—Contents of a PREP element in Case C 1404
Table 13-20—Contents of a PREP element in Case D 1405
Table 13-21—Contents of a PERR element in Case A 1407
Table 13-23—Contents of a PERR element in Case C 1408
Table 13-22—Contents of a PERR element in Case B 1408
Table 13-24—Contents of a PERR element in Case D 1409
Table 13-25—Contents of a RANN element in Case A 1411
Table 13-26—Contents of a RANN element in Case B 1412
Table 13-27—Contents of a GANN element in Case A 1414
Table 13-28—Contents of a GANN element in Case B 1415
Table 13-29—Contents of a PXU element 1420
Table 13-30—Contents of a PXUC element 1421
Table 13-31—Peer-specific mesh power mode definition 1434
Table 13-32—Mesh peer service period triggering with RSPI and EOSP field combinations in peer trigger frame 1440
Table 14-1—TXVECTOR parameters 1443
Table 14-2—RXVECTOR parameters 1444
Table 14-3—PSF bit descriptions 1447
Table 14-4—PLCP field bit descriptions 1451

Table 14-5—PMD_SAP peer-to-peer service primitives 1461
Table 14-6—PMD_SAP sublayer-to-sublayer service primitives 1462
Table 14-7—List of parameters for PMD primitives 1462
Table 14-8—Transmit power levels 1465
Table 14-9—Operating frequency range 1468
Table 14-10—Number of operating channels 1468
Table 14-11—Requirements in China, North America and Europe (excluding Spain and France; values specified in GHz) 1469
Table 14-12—Requirements in Japan (values specified in GHz) 1470
Table 14-13—Requirements in Spain (values specified in GHz) 1470
Table 14-14—Requirements in France (values specified in GHz) 1470
Table 14-15—Base-Hopping sequence b(i) for China, North America and most of Europe 1472
Table 14-16—Base-Hopping sequence b(i) for Spain 1472
Table 14-17—Base-Hopping sequence b(i) for France 1472
Table 14-18—Symbol encoding into carrier deviation (1 Mb/s, 2GFSK) 1474
Table 14-19—1 Mb/s Dp 1477
Table 14-20—Symbol encoding into carrier deviation 1478
Table 14-21—2 Mb/s Dp 1480
Table 14-22—FHSS PHY attributes 1481
Table 14-23—Regulatory domain codes 1482
Table 14-24—Supported data rate codes (dot11SupportedDataRatesTX) 1483
Table 14-25—Supported data rate codes (dot11SupportedDataRatesRX) 1483
Table 14-26—Number of transmit antennas 1484
Table 14-27—Number of receive antennas 1484
Table 14-28—Diversity support codes 1485
Table 14-29—Diversity select antenna codes 1485
Table 14-30—Transmit power levels 1486
Table 14-31—FH PHY characteristics 1487
Table 15-2—Sixteen-PPM basic rate mapping 1495
Table 15-1—IR PMD_SAP peer-to-peer service primitives 1495
Table 15-3—Four-PPM enhanced rate mapping 1496
Table 15-4—Peak optical power as a function of emitter radiation pattern mask 1497
Table 15-5—Definition of the emitter radiation pattern Mask 1 1498
Table 15-6—Definition of emitter radiation pattern Mask 2 1498
Table 15-7—Definition of the receiver FOV 1501
Table 15-9—IR PHY characteristics 1503
Table 15-8—IR PHY MIB attributes 1503
Table 16-1—MIB attribute default values/ranges 1513
Table 16-2—DS PHY characteristics 1514
Table 16-3—PMD_SAP peer-to-peer service primitives 1516
Table 16-4—DSSS PMD_SAP peer-to-peer service primitives 1516
Table 16-5—PMD_SAP sublayer-to-sublayer service primitives 1518
Table 16-6—List of parameters for the PMD primitives 1518
Table 16-7—DSSS PHY frequency channel plan 1527
Table 16-8—1 Mb/s DBPSK encoding table 1528
Table 16-9—2 Mb/s DQPSK encoding table 1528
Table 17-1—SERVICE field definitions 1540
Table 17-2—Example of LENGTH calculations for CCK 1541
Table 17-3—Example of LENGTH calculations for PBCC 1542
Table 17-4—MIB attribute default values/ranges 1551
Table 17-5—High Rate PHY characteristics 1552
Table 17-6—Parameter vectors 1553
Table 17-7—PMD_SAP peer-to-peer service primitives 1555
Table 17-8—PMD_SAP sublayer-to-sublayer service primitives 1556

Table 17-9—High Rate PHY frequency channel plan 1566
Table 17-10—1 Mb/s DBPSK encoding table 1567
Table 17-11—2 Mb/s DQPSK encoding table 1567
Table 17-12—DQPSK encoding table 1568
Table 17-14—QPSK encoding table 1569
Table 17-13—5.5 Mb/s CCK encoding table 1569
Table 17-15—China and North American operating channels 1573
Table 17-16—European operating channels (except France and Spain) 1573
Table 17-17—China and North American Set 1 hop patterns 1574
Table 17-18—European Set 1 hop patterns (except France and Spain) 1574
Table 18-1—TXVECTOR parameters 1585
Table 18-2—RXVECTOR parameters 1586
Table 18-3—TXSTATUS parameters 1587
Table 18-4—Modulation-dependent parameters 1590
Table 18-5—Timing-related parameters 1590
Table 18-6—Contents of the SIGNAL field 1595
Table 18-7—Modulation-dependent normalization factor K_{MOD} 1600
Table 18-8—BPSK encoding table 1602
Table 18-9—QPSK encoding table 1602
Table 18-10—16-QAM encoding table 1602
Table 18-11—64-QAM encoding table 1602
Table 18-12—Major parameters of the OFDM PHY 1605
Table 18-13—Allowed relative constellation error versus data rate 1610
Table 18-14—Receiver performance requirements 1612
Table 18-15—Optional enhanced receiver performance requirements 1613
Table 18-16—MIB attribute default values/ranges 1620
Table 18-17—OFDM PHY characteristics 1623
Table 18-19—PMD_SAP sublayer-to-sublayer service primitives 1625
Table 18-20—List of parameters for the PMD primitives 1625
Table 18-18—PMD_SAP peer-to-peer service primitives 1625
Table 19-1—TXVECTOR parameters 1633
Table 19-2—TXSTATUS parameters 1634
Table 19-3—RXVECTOR parameters 1634
Table 19-4—SERVICE field bit definitions 1636
Table 19-5—Example of LENGTH calculations for ERP-PBCC-22 1637
Table 19-6—CCA parameters 1646
Table 19-7—MIB attribute default values/ranges 1659
Table 19-8—ERP characteristics 1663
Table 19-10—PMD_SAP sublayer-to-sublayer services 1665
Table 19-11—List of parameters for the PMD primitives 1665
Table 19-9—PMD_SAP peer-to-peer services 1665
Table 20-1—TXVECTOR and RXVECTOR parameters 1671
Table 20-2—PPDU format as a function of CH_BANDWIDTH and CH_OFFSET parameters 1678
Table 20-3—Mapping of the HT PHY parameters for NON_HT operation 1679
Table 20-4—TXSTATUS parameter 1681
Table 20-5—Elements of the HT PLCP packet 1682
Table 20-6—Timing-related constants 1689
Table 20-7—Frequently used parameters 1690
Table 20-8—Value of tone scaling factor 1693
Table 20-9—Cyclic shift for non-HT portion of packet 1695
Table 20-10—Cyclic shift values of HT portion of packet 1698
Table 20-11—HT-SIG fields 1699
Table 20-12—Determining the number of space-time streams 1704
Table 20-13—Number of HT-DLTFs required for data space-time streams 1704

Table 20-14—Number of HT-ELTFs required for extension spatial streams 1704
Table 20-15—LDPC parameters 1712
Table 20-16—PPDU encoding parameters 1714
Table 20-17—Number of rows and columns in the interleaver 1717
Table 20-18—Constellation mapper output to spatial mapper input for STBC 1719
Table 20-19—Pilot values for 20 MHz transmission 1721
Table 20-20—Pilots values for 40 MHz transmission (excluding MCS 32) 1721
Table 20-21—Maximum available space-time streams 1737
Table 20-22—Allowed relative constellation error versus constellation size and coding rate 1742
Table 20-23—Receiver minimum input level sensitivity 1745
Table 20-24—HT PHY MIB attributes 1756
Table 20-25—MIMO PHY characteristics 1761
Table 20-26—PMD_SAP peer-to-peer service primitives 1763
Table 20-27—PMD_SAP sublayer-to-sublayer service primitives 1763
Table 20-28—List of parameters for PMD primitives 1764
Table 20-29—Symbols used in MCS parameter tables 1771
Table 20-30—MCS parameters for mandatory 20 MHz, N_{SS} = 1, N_{ES} = 1 1771
Table 20-31—MCS parameters for optional 20 MHz, N_{SS} = 2, N_{ES} = 1, EQM 1772
Table 20-32—MCS parameters for optional 20 MHz, N_{SS} = 3, N_{ES} = 1, EQM 1772
Table 20-33—MCS parameters for optional 20 MHz, N_{SS} = 4, N_{ES} = 1, EQM 1773
Table 20-34—MCS parameters for optional 40 MHz, N_{SS} = 1, N_{ES} = 1 1773
Table 20-35—MCS parameters for optional 40 MHz, N_{SS} = 2, N_{ES} = 1, EQM 1774
Table 20-36—MCS parameters for optional 40 MHz, N_{SS} = 3, EQM 1774
Table 20-37—MCS parameters for optional 40 MHz, N_{SS} = 4, EQM 1775
Table 20-38—MCS parameters for optional 40 MHz MCS 32 format, N_{SS} = 1, N_{ES} = 1 1775
Table 20-39—MCS parameters for optional 20 MHz, N_{SS} = 2, NES = 1, UEQM 1775
Table 20-40—MCS parameters for optional 20 MHz, N_{SS} = 3, N_{ES} = 1, UEQM 1776
Table 20-41—MCS parameters for optional 20 MHz, N_{SS} = 4, N_{ES} = 1, UEQM 1776
Table 20-42—MCS parameters for optional 40 MHz, N_{SS} = 2, N_{ES} = 1, UEQM 1778
Table 20-43—MCS parameters for optional 40 MHz, N_{SS} = 3, UEQM 1778
Table 20-44—MCS parameters for optional 40 MHz, N_{SS} = 4, UEQM 1779
Table D-1—Regulatory requirement list 2287
Table D-2—Behavior limits sets 2288
Table D-3—Maximum STA transmit power classification for the 5.85–5.925 GHz band in the United States 2289
Table D-4—Spectrum mask data for 5 MHz channel spacing 2290
Table D-5—Spectrum mask data for 10 MHz channel spacing 2290
Table D-6—Spectrum mask data for 20 MHz channel spacing 2290
Table E-1—Operating classes in the United States 2294
Table E-2—Operating classes in Europe 2295
Table E-3—Operating classes in Japan 2297
Table E-4—Global operating classes 2299
Table E-5—DSE timer limits 2303
Table F-1—Matrix prototypes for codeword block length n=648 bits, subblock size is Z = 27 bits 2304
Table F-2—Matrix prototypes for codeword block length n=1296 bits, subblock size is Z= 54 bits 2305
Table F-3—Matrix prototypes for codeword block length n=1944 bits, subblock size is Z = 81 bits 2306
Table G-1—Attributes applicable to frame exchange sequence definition 2307
Table H-1—Payload Type field values 2320
Table I-1—Hopping sequence set 1 2322
Table I-2—Hopping sequence set 2 2326
Table I-3—Hopping sequence set 3 2330
Table L-1—The message for the BCC example 2537
Table L-2—Frequency domain representation of the short sequences 2538
Table L-3—One period of IFFT of the short sequences 2538

Table L-4—Time domain representation of the short sequence 2539
Table L-5—Frequency domain representation of the long sequences 2541
Table L-6—Time domain representation of the long sequence 2541
Table L-7—Bit assignment for SIGNAL field 2543
Table L-9—SIGNAL field bits after interleaving 2544
Table L-8—SIGNAL field bits after encoding 2544
Table L-11—Frequency domain representation of SIGNAL field with pilots inserted 2545
Table L-10—Frequency domain representation of SIGNAL field 2545
Table L-12—Time domain representation of SIGNAL field 2546
Table L-13—The DATA bits before scrambling 2547
Table L-15—The DATA bits after scrambling 2549
Table L-14—Scrambling sequence for seed 1011101 2549
Table L-16—The BCC encoded DATA bits 2551
Table L-17—First permutation 2552
Table L-18—Second permutation 2553
Table L-19—Interleaved bits of first DATA symbol 2554
Table L-20—Frequency domain of first DATA symbol 2555
Table L-21—Polarity of the pilot subcarriers 2556
Table L-22—Time domain representation of the short training sequence 2557
Table L-23—Time domain representation of the long training sequence 2558
Table L-24—Time domain representation of the SIGNAL field (1 symbol) 2559
Table L-25—Time domain representation of the DATA field: symbol 1of 6 2560
Table L-26—Time domain representation of the DATA field: symbol 2 of 6 2561
Table L-27—Time domain representation of the DATA field: symbol 3 of 6 2562
Table L-28—Time domain representation of the DATA field: symbol 4 of 6 2562
Table L-29—Time domain representation of the DATA field: symbol 5 of 6 2563
Table L-30—Time domain representation of the DATA field: symbol 6 of 6 2564
Table L-31—Message for LDPC example 1 2565
Table L-32—DATA bits for LDPC example 1 before scrambling 2566
Table L-33—DATA bits for LDPC example 1 after scrambling 2568
Table L-34—DATA bits for LDPC example 1 after insertion of shortening bits 2569
Table L-35—DATA bits for LDPC example 1 after LDPC encoding 2571
Table L-36—DATA bits after puncturing and removal of shortening bits 2574
Table L-37—Message for LDPC example 2 2577
Table L-38—DATA bits for LDPC example 2 before scrambling 2578
Table L-39—DATA bits for LDPC example 2 after scrambling 2580
Table L-40—DATA bits for LDPC example 2 after insertion of shortening bits 2582
Table L-41—DATA bits for LDPC example 2 after LDPC encoding 2584
Table L-42—DATA bits after removal of shortening bits and copying of repetition bits 2587
Table M-1—Test vectors for block function 2604
Table M-2—Test vectors for Michael 2604
Table M-4—Sample plaintext MPDU 2619
Table M-5—ARC4 encryption 2619
Table M-3—Notation example 2619
Table M-7—Sample TKIP parameters 2620
Table M-6—Expanded MPDU after WEP encapsulation 2620
Table M-8—Sample plaintext and cipher text MPDUs, using parameter from Table M-7 2621
Table M-9—RSN PRF Test Vector 1 2622
Table M-10—RSN PRF Test Vector 2 2622
Table M-11—RSN PRF Test Vector 3 2622
Table M-13—Sample values for pairwise key derivations 2623
Table M-14—Sample derived CCMP temporal key (TK) 2623
Table M-12—RSN PRF Test Vector 4 2623
Table M-15—Sample derived PTK 2624

Table N-1—Admissible TSPECs 2628
Table P-1—IEEE 802.11 integration service STT 2646
Table P-2—Ethernet/IEEE 802.3 to IEEE 802.11 translation 2647
Table P-3—IEEE 802.11 to Ethernet/IEEE 802.3 translation 2647
Table U-1—Destination URI payload 2670
Table V-1—Mapping table of DSCP to 3GPP QoS information and EDCA ACs 2678
Table V-2—Example Enterprise DSCP to UP/AC mapping 2678
Table V-3—UP to DSCP range mapping example 2679
Table V-4—SSPN Interface information or permission parameters 2680
Table W-1—Default parameters for mesh STAs that intend to operate in light or deep sleep mode for mesh peerings 2690

Figures

Figure A—Changes in clause numbers and annex letters from 2007 revision to 2012 revision x
Figure 4-1—BSSs 46
Figure 4-2—DSs and APs 47
Figure 4-3—ESS 48
Figure 4-4—A representative signal intensity map 50
Figure 4-5—Collocated coverage areas 50
Figure 4-6—Connecting to other IEEE 802 LANs 51
Figure 4-7—SSPN interface service architecture 61
Figure 4-8—Example MBSS containing mesh STAs, mesh gates, APs, and portals 63
Figure 4-9—Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS 64
Figure 4-10—MAC data transport over an MBSS 66
Figure 4-11—Complete IEEE 802.11 architecture 69
Figure 4-12—IEEE 802.11 architecture (again) 80
Figure 4-13—Logical architecture of an IBSS 80
Figure 4-14—Portion of the ISO/IEC basic reference model covered in this standard 81
Figure 4-15—Interworking reference model 82
Figure 4-16—ESS link illustration 83
Figure 4-17—Establishing the IEEE 802.11 association 84
Figure 4-18—IEEE 802.1X EAP authentication 85
Figure 4-19—Establishing pairwise and group keys 86
Figure 4-20—Delivery of subsequent group keys 87
Figure 4-21—Example using SAE Authentication 87
Figure 4-22—Sample 4-Way Handshakes in an IBSS 89
Figure 4-23—Example using IEEE 802.1X authentication 90
Figure 5-1—MAC data plane architecture 96
Figure 6-1—GET and SET operations 104
Figure 6-2—Layer management model 153
Figure 6-3—Measurement request—accepted 154
Figure 6-4—Measurement request—rejected 154
Figure 6-5—TPC adaptation 155
Figure 6-6—Channel switch 155
Figure 6-7—TDLS direct-link establishment 229
Figure 6-8—TDLS direct-link teardown 235
Figure 6-9—TDLS Peer U-APSD 237
Figure 6-10—TDLS channel switching 240
Figure 6-11—TDLS Peer PSM 244
Figure 6-12—Event protocol exchange 247
Figure 6-13—Diagnostic protocol exchange 252
Figure 6-14—Location configuration request and response protocol exchange 255
Figure 6-15—Location track notification protocol exchange 259
Figure 6-16—Timing measurement primitives and timestamps capture 261
Figure 6-17—BSS Transition Management request—accepted 265
Figure 6-18—FMS setup protocol exchange 272
Figure 6-19—Collocated interference protocol exchange 275
Figure 6-20—TFS request and response exchange 279
Figure 6-21—Sleep mode request and response exchange 283
Figure 6-22—TIM broadcast setup protocol exchange 287
Figure 6-23—QoS traffic capability update protocol exchange 290
Figure 6-24—Channel usage request protocol exchange 292
Figure 6-25—DMS setup protocol exchange 296
Figure 6-26—MSGCF state machine 342

Figure 8-1—MAC frame format 381
Figure 8-2—Frame Control field 382
Figure 8-3—Sequence Control field 388
Figure 8-4—QoS AP PS Buffer State subfield 393
Figure 8-5—HT Control field 394
Figure 8-6—Link Adaptation Control subfield 395
Figure 8-7—MAI subfield 395
Figure 8-8—ASELC subfield 396
Figure 8-10—Mesh Flags subfield 399
Figure 8-9—Mesh Control field 399
Figure 8-11—Mesh Address Extension subfield 400
Figure 8-12—Frame Control field subfield values within control frames 404
Figure 8-13—RTS frame 404
Figure 8-14—CTS frame 405
Figure 8-15—ACK frame 405
Figure 8-16—PS-Poll frame 406
Figure 8-17—CF-End frame 406
Figure 8-18—CF-End+CF-Ack frame 407
Figure 8-19—BlockAckReq frame 407
Figure 8-20—BAR Control field 407
Figure 8-22—BAR Information field (Multi-TID BlockAckReq) 409
Figure 8-23—Per TID Info subfield 409
Figure 8-21—Block Ack Starting Sequence Control field 409
Figure 8-24—BlockAck frame 410
Figure 8-25—BA Control field 410
Figure 8-26—BA Information field (BlockAck) 411
Figure 8-27—BA Information field (Compressed BlockAck) 412
Figure 8-28—BA Information field (Multi-TID BlockAck) 412
Figure 8-29—Control Wrapper frame 413
Figure 8-30—Data frame 413
Figure 8-31—A-MSDU structure 416
Figure 8-32—A-MSDU subframe structure 416
Figure 8-33—A-MSDU Subframe structure for Mesh Data 417
Figure 8-34—Management frame format 418
Figure 8-35—Authentication Algorithm Number field 437
Figure 8-36—Authentication Transaction Sequence Number field 438
Figure 8-37—Beacon Interval field 438
Figure 8-38—Capability Information field 438
Figure 8-40—Listen Interval field 442
Figure 8-41—Reason Code field 442
Figure 8-39—Current AP Address field 442
Figure 8-42—AID field 445
Figure 8-43—Status Code field 445
Figure 8-44—Timestamp field 449
Figure 8-45—Action field 449
Figure 8-46—Dialog Token fixed field 451
Figure 8-47—DLS Timeout Value fixed field 451
Figure 8-48—Block Ack Parameter Set fixed field 451
Figure 8-49—Block Ack Timeout Value fixed field 452
Figure 8-50—DELBA Parameters fixed field 452
Figure 8-52—QoS Info field when set by a non-AP STA 453
Figure 8-51—QoS Info field when sent by an AP 453
Figure 8-53—Measurement Pilot Interval fixed field 454
Figure 8-54—Max Transmit Power field 454

Figure 8-55—Transmit Power Used field 454
Figure 8-56—Channel Width fixed field 455
Figure 8-57—SM Power Control fixed field 455
Figure 8-59—PSMP Parameter Set fixed field 456
Figure 8-58—PCO Phase Control fixed field 456
Figure 8-60—PSMP STA Info fixed field (group addressed) 457
Figure 8-61—PSMP STA Info fixed field (individually addressed) 457
Figure 8-62—MIMO Control field 458
Figure 8-63—CSI matrix coding 461
Figure 8-64—V matrix coding (noncompressed beamforming) 463
Figure 8-65—First example of Compressed Beamforming Report field encoding 466
Figure 8-66—Second example of Compressed Beamforming Report field encoding 466
Figure 8-67—Antenna Selection Indices fixed field 466
Figure 8-68—Organization Identifier field 467
Figure 8-69—Identification field format 467
Figure 8-70—Mask field format 467
Figure 8-71—GAS Query Response Fragment ID field 468
Figure 8-72—Venue Info field format 468
Figure 8-73—Target Channel field format 471
Figure 8-74—Operating Channel field format 472
Figure 8-75—Send-Confirm field 472
Figure 8-76—Anti-Clogging Token field 472
Figure 8-77—Scalar field 472
Figure 8-78—Element field 472
Figure 8-79—Confirm field 473
Figure 8-80—Finite Cyclic Group field 473
Figure 8-81—Element format 474
Figure 8-82—SSID element format 478
Figure 8-84—FH Parameter Set element format 479
Figure 8-83—Supported rates element format 479
Figure 8-85—DSSS Parameter Set element format 480
Figure 8-86—CF Parameter Set element format 480
Figure 8-87—TIM element format 481
Figure 8-88—IBSS Parameter Set element format 482
Figure 8-89—Challenge Text element format 483
Figure 8-90—Country element format 483
Figure 8-91—Hopping Pattern Parameters element 485
Figure 8-92—Hopping Pattern Table element 486
Figure 8-93—Request element 486
Figure 8-94—ERP element 487
Figure 8-95—ERP Parameters field 487
Figure 8-96—Extended Supported Rates element format 488
Figure 8-97—Power Constraint element format 488
Figure 8-98—Power Capability element format 488
Figure 8-99—TPC Request element format 489
Figure 8-100—TPC Report element format 489
Figure 8-101—Supported Channels element format 490
Figure 8-102—Channel Switch Announcement element format 490
Figure 8-103—Secondary Channel Offset element format 491
Figure 8-104—Measurement Request element format 492
Figure 8-105—Measurement Request Mode field 492
Figure 8-106—Measurement Request field format for a basic request 494
Figure 8-107—Measurement Request field format for a CCA request 495
Figure 8-108—Measurement Request field format for a RPI histogram request 495

Figure 8-109—Measurement Request field format for Channel Load Request 496
Figure 8-111—Measurement Request field format for Noise Histogram Request 497
Figure 8-110—Channel Load Reporting Information data field format 497
Figure 8-112—Noise Histogram Reporting Information data field format 498
Figure 8-113—Measurement Request field format for Beacon Request 499
Figure 8-114—Beacon Reporting Information data field format 501
Figure 8-115—Measurement Request field format for frame request 502
Figure 8-116—Measurement Request field format for STA Statistics Request 503
Figure 8-117—Triggered Reporting subelement for STA Counters 505
Figure 8-118—STA Counter Trigger Condition field 505
Figure 8-119—Triggered Reporting subelement for QoS STA Counters 506
Figure 8-120—QoS STA Counter Trigger Condition field 506
Figure 8-122—RSNA Trigger Condition field 507
Figure 8-121—Triggered Reporting subelement for RSNA Counters 507
Figure 8-123—Measurement Request field format for LCI Request 508
Figure 8-124—Azimuth Request subelement format 509
Figure 8-125—Azimuth Request field 509
Figure 8-126—Originator Requesting STA MAC Address subelement format 510
Figure 8-127—Target MAC Address subelement format 510
Figure 8-128—Measurement Request field format for Transmit Stream/Category Measurement Request 510
Figure 8-130—Triggered Reporting subelement format 511
Figure 8-129—Traffic Identifier field 511
Figure 8-131—Triggered Reporting field 512
Figure 8-132—Trigger Conditions bit-field 512
Figure 8-134—Measurement Request field format for measurement pause request 513
Figure 8-133—Delay Threshold subfield 513
Figure 8-135—Measurement Request field format for a Multicast Diagnostics Request 514
Figure 8-136—Multicast Triggered Reporting subelement format 515
Figure 8-137—Multicast Trigger Condition field 515
Figure 8-138—Location Civic Request field format 516
Figure 8-139—Location Identifier Request field format 518
Figure 8-140—Measurement Report element format 519
Figure 8-141—Measurement Report Mode field 519
Figure 8-142—Measurement Report field format for a basic report 521
Figure 8-143—Map field format 521
Figure 8-145—Measurement Report field format for an RPI histogram report 522
Figure 8-144—Measurement Report field format for a CCA report 522
Figure 8-146—Measurement Report field format for Channel Load Report 523
Figure 8-147—Measurement Report field format for Noise Histogram Report 524
Figure 8-148—Measurement Report field format for Beacon Report 526
Figure 8-149—Reported Frame Information field 526
Figure 8-150—Measurement Report field format for Frame Report 528
Figure 8-151—Frame Count Report subelement format 529
Figure 8-152—Frame Report Entry field format 529
Figure 8-153—Measurement Report field format for STA Statistics Report 530
Figure 8-154—Measurement Report field format for dot11Counters Group 535
Figure 8-155—Measurement Report field format for dot11MACStatistics Group 535
Figure 8-157—Measurement Report field format for dot11BSSAverageAccessDelay Group 536
Figure 8-156—Measurement Report field format for dot11QosCounters Group for UPx 536
Figure 8-158—Measurement Report field format for RSNA Counters Group 537
Figure 8-159—Reporting Reason subelement for STA Counters 537
Figure 8-160—Reporting Reason subelement for QoS STA Counters 538
Figure 8-161—Reporting Reason subelement for RSNA Counters 538

Figure 8-162—Measurement Report field format for Location Configuration Information Report 539
Figure 8-163—Azimuth Report subelement format 540
Figure 8-164—Azimuth Report subfield 540
Figure 8-165—Measurement Report field format for Transmit Stream/Category Measurement Report ... 541
Figure 8-166—Reporting Reason field 542
Figure 8-167—Measurement Report field format for a Multicast Diagnostics Report 544
Figure 8-168—Multicast Reporting Reason field 544
Figure 8-169—Location Civic Report field format 546
Figure 8-170—Location Reference subelement format 547
Figure 8-171—Location Shape subelement format 548
Figure 8-172—2-Dimension Point Location Shape Value format 549
Figure 8-173—3-Dimension Point Location Shape Value format 549
Figure 8-174—Circle Location Shape Value format 549
Figure 8-175—Sphere Location Shape Value format 549
Figure 8-176—Polygon Location Shape Value format 550
Figure 8-177—Prism Location Shape Value format 550
Figure 8-178—Ellipse Location Shape Value format 550
Figure 8-179—Ellipsoid Location Shape Value format 551
Figure 8-180—Arcband Location Shape Value format 551
Figure 8-181—Map Image subelement format 551
Figure 8-182—Location Identifier Report field format 552
Figure 8-184—IBSS DFS element format 554
Figure 8-185—Channel Map field format 554
Figure 8-183—Quiet element format 554
Figure 8-186—RSNE format 555
Figure 8-187—Suite selector format 557
Figure 8-188—RSN Capabilities field format 560
Figure 8-188—RSN Capabilities field format 560
Figure 8-189—Vendor Specific element format 562
Figure 8-190—Extended Capabilities element format 562
Figure 8-191—BSS Load element format 566
Figure 8-192—EDCA Parameter Set element 567
Figure 8-193—AC_BE, AC_BK, AC_VI, and AC_VO Parameter Record field format 567
Figure 8-194—ACI/AIFSN field 568
Figure 8-195—ECWmin and ECWmax fields 568
Figure 8-196—TSPEC element format 569
Figure 8-197—TS Info field 570
Figure 8-198—Nominal MSDU Size field 572
Figure 8-200—Frame Classifier field 574
Figure 8-199—TCLAS element format 574
Figure 8-202—Frame Classifier field of Classifier Type 1 for traffic over IPv4 575
Figure 8-203—Frame Classifier field of Classifier Type 1 for traffic over IPv6 575
Figure 8-204—Frame Classifier field of Classifier Type 2 575
Figure 8-201—Frame Classifier field of Classifier Type 0 575
Figure 8-205—Frame Classifier field of Classifier Type 3 576
Figure 8-206—Frame Classifier subfield of Classifier Type 4 for traffic over IPv4 577
Figure 8-207—Frame Classifier subfield of Classifier Type 4 for traffic over IPv6 577
Figure 8-208—Frame Classifier field of Classifier Type 5 578
Figure 8-209—TS Delay element 578
Figure 8-210—TCLAS Processing element 578
Figure 8-211—Schedule element 579
Figure 8-212—Schedule Info field 579
Figure 8-213—QoS Capability element format 580
Figure 8-214—AP Channel Report element format 580

Figure 8-216—BSSID Information field 581
Figure 8-215—Neighbor Report element format 581
Figure 8-217—Capabilities subfield 582
Figure 8-218—TSF Information subelement format 583
Figure 8-219— BSS Transition Candidate Preference subelement field format 584
Figure 8-221—Bearing subelement field format 585
Figure 8-220—BSS Termination Duration subelement field format 585
Figure 8-223—BSS Average Access Delay element format 586
Figure 8-222—RCPI element format 586
Figure 8-224—Antenna element format 587
Figure 8-225—RSNI element format 588
Figure 8-226—Measurement Pilot Transmission element format 588
Figure 8-227—BSS Available Admission Capacity element format 589
Figure 8-228—BSS AC Access Delay element format 590
Figure 8-229—Access Category Access Delay subfields 591
Figure 8-230—RM Enabled Capabilities element format 592
Figure 8-231—Multiple BSSID element format 594
Figure 8-232—MDE format 596
Figure 8-233—FT Capability and Policy field 596
Figure 8-234—FTE format 596
Figure 8-235—MIC Control field 597
Figure 8-236—Optional Parameter(s) field 597
Figure 8-237—GTK subelement format 598
Figure 8-238—GTK subelement's Key Info subfield 598
Figure 8-239—IGTK subelement format 598
Figure 8-240—TIE format 599
Figure 8-241—RDE format 599
Figure 8-242—RIC Descriptor element format 600
Figure 8-243—DSE Registered Location element format 600
Figure 8-244—DSE registered location element body fields format 601
Figure 8-245—Extended Channel Switch Announcement element format 602
Figure 8-246—Supported Operating Classes element format 603
Figure 8-247—Management MIC element format 603
Figure 8-248—HT Capabilities element format 604
Figure 8-249—HT Capabilities Info field 604
Figure 8-250—A-MPDU Parameters field 606
Figure 8-251—Supported MCS Set field 607
Figure 8-252—HT Extended Capabilities field 608
Figure 8-253—Transmit Beamforming Capabilities field 610
Figure 8-254—ASEL Capability field 612
Figure 8-255—HT Operation element format 613
Figure 8-256—HT Operation Information field 614
Figure 8-257—20/40 BSS Intolerant Channel Report element format 617
Figure 8-258—Overlapping BSS Scan Parameters element format 618
Figure 8-260—20/40 BSS Coexistence Information field 619
Figure 8-259—20/40 BSS Coexistence element format 619
Figure 8-261—Time Advertisement element format 620
Figure 8-262—Link Identifier element format 621
Figure 8-263—Wakeup Schedule element format 621
Figure 8-264—Channel Switch Timing element format 622
Figure 8-266—TPU Buffer Status element format 623
Figure 8-265—PTI Control element format 623
Figure 8-267—Event Request element format 624
Figure 8-268—Transition Target BSSID subelement format 625

Figure 8-269—Transition Source BSSID subelement format 625
Figure 8-270—Transition Time Threshold subelement format 626
Figure 8-271—Transition Result subelement format 626
Figure 8-272—Match Value field definitions 626
Figure 8-273—Frequent Transition subelement format 627
Figure 8-275—Authentication Type subelement format 628
Figure 8-276—EAP Method subelement format 628
Figure 8-274—RSNA Target BSSID subelement format 628
Figure 8-277—RSNA Result subelement format 629
Figure 8-278—Match Value field definitions 629
Figure 8-280—Channel Number subelement format 630
Figure 8-279—Peer Address subelement format 630
Figure 8-281—Event Report element format 631
Figure 8-282—Event Report format for Transition event 632
Figure 8-283—Event Report format for RSNA event 634
Figure 8-284—Event Report format for Peer-to-Peer Link event 634
Figure 8-285—Event Report format for WNM Log event 635
Figure 8-286—Diagnostic Request element format 636
Figure 8-287—Diagnostic Information subelement format 638
Figure 8-288—Credential Type subelement format 639
Figure 8-289—AKM Suite subelement format 639
Figure 8-290—AP Descriptor subelement format 639
Figure 8-291—Antenna Type subelement format 640
Figure 8-292—Cipher Suite subelement format 640
Figure 8-293—Collocated Radio Type subelement format 640
Figure 8-294—Device Type subelement format 641
Figure 8-295—EAP Method subelement format 642
Figure 8-296—Firmware Version subelement format 643
Figure 8-297—MAC Address subelement format 643
Figure 8-298—Manufacturer ID String subelement format 643
Figure 8-299—Manufacturer Model String subelement format 643
Figure 8-300—Manufacturer OI subelement format 644
Figure 8-301—Manufacturer Serial Number String subelement format 644
Figure 8-302—Power Save Mode subelement format 644
Figure 8-303— Profile ID subelement format 645
Figure 8-304—Supported Operating Classes subelement format 645
Figure 8-305—Status Code subelement format 645
Figure 8-306—SSID subelement format 646
Figure 8-307—Tx Power Capability subelement format 646
Figure 8-308—Certificate ID subelement format 646
Figure 8-309—Diagnostic Report element format 647
Figure 8-310—Location Parameters element format 649
Figure 8-311—Location Indication Parameters subelement 650
Figure 8-312—Location Indication Channels subelement 652
Figure 8-313—Channel Entry field format 652
Figure 8-315—Radio Information subelement 653
Figure 8-314—Location Status subelement 653
Figure 8-316—Motion subelement 654
Figure 8-317—Location Indication Broadcast Data Rate subelement 655
Figure 8-319—Location Indication Options subelement 656
Figure 8-320—Options Used field format 656
Figure 8-318—Time of Departure subelement 656
Figure 8-321—Nontransmitted BSSID Capability element format 657
Figure 8-322—SSID List element format 657

Figure 8-323—Multiple BSSID-Index element format 658
Figure 8-324—FMS Descriptor element format 658
Figure 8-325—FMS Counter format 659
Figure 8-326—FMS Request element format 659
Figure 8-327—FMS Subelement format 660
Figure 8-328—FMS Response element format 661
Figure 8-329—FMS Status Subelement format 662
Figure 8-330—TCLAS Status Subelement format 663
Figure 8-331—QoS Traffic Capability Element format 663
Figure 8-332—BSS Max Idle Period element format 665
Figure 8-333—Idle Options field 665
Figure 8-334—TFS Request element format 666
Figure 8-335—TFS Subelement format 667
Figure 8-336—TFS Response element format 667
Figure 8-337—TFS Status Subelement format 668
Figure 8-338—WNM-Sleep Mode element format 668
Figure 8-339—TIM Broadcast Request element format 670
Figure 8-340—TIM Broadcast Response element format 670
Figure 8-341— Collocated Interference Report element format 671
Figure 8-342—Interference Level Accuracy/Interference Index field format 672
Figure 8-343—Channel Usage element format 673
Figure 8-344—Time Zone element format 674
Figure 8-345—DMS Request element format 674
Figure 8-346—DMS Descriptor 675
Figure 8-347—DMS Response element format 676
Figure 8-348—DMS Status field format 676
Figure 8-349—Destination URI element format 678
Figure 8-350—U-APSD Coexistence element format 679
Figure 8-351—Interworking element format 680
Figure 8-352—Access Network Options field format 680
Figure 8-354—Advertisement Protocol Tuple field format 682
Figure 8-355—Query Response Info field format 682
Figure 8-353—Advertisement Protocol element format 682
Figure 8-356—Expedited Bandwidth Request element format 683
Figure 8-357—QoS Map Set element description 684
Figure 8-358—DSCP Exception format 684
Figure 8-359—DSCP Range description 685
Figure 8-360—Roaming Consortium element format 685
Figure 8-362—Emergency Alert Identifier element format 686
Figure 8-363—Mesh Configuration element format 686
Figure 8-361—OI #1 and #2 Lengths field format 686
Figure 8-364—Mesh Formation Info field 689
Figure 8-365—Mesh Capability field 690
Figure 8-366—Mesh ID element format 690
Figure 8-367—Mesh Link Metric Report element format 691
Figure 8-368—Flags field 691
Figure 8-370—Mesh Peering Management element format 692
Figure 8-369—Congestion Notification element format 692
Figure 8-371—Mesh Channel Switch Parameters element format 693
Figure 8-372—Flags field 694
Figure 8-373—Mesh Awake Window element format 694
Figure 8-374—Beacon Timing element format 695
Figure 8-375—Report Control field 695
Figure 8-376—Beacon Timing Information field 695

Figure 8-377—MCCAOP Setup Request element format 696
Figure 8-378—MCCAOP Reservation field 697
Figure 8-379—MCCAOP Setup Reply element format 697
Figure 8-380—MCCAOP Advertisement Overview element format 698
Figure 8-381—Flags field format 699
Figure 8-382—MCCAOP Advertisement element format 699
Figure 8-383—MCCAOP Advertisement Element Information field 700
Figure 8-385—MCCAOP Teardown element format 701
Figure 8-386—GANN element format 701
Figure 8-384—MCCAOP Reservation Report field 701
Figure 8-387—RANN element format 702
Figure 8-388—Flags field format 702
Figure 8-389—PREQ element format 703
Figure 8-390—Flags field format 704
Figure 8-391—Per Target Flags field format 705
Figure 8-393—Flags field format 706
Figure 8-392—PREP element format 706
Figure 8-394—PERR element format 707
Figure 8-395—Flags field format 707
Figure 8-396—PXU element format 708
Figure 8-398—Flags subfield 709
Figure 8-397—Proxy Information field 709
Figure 8-400—Authenticated Mesh Peering Exchange element format 710
Figure 8-399—PXUC element format 710
Figure 8-401—MIC element format 711
Figure 8-402—Subelement format 711
Figure 8-403—ANQP-element format 712
Figure 8-404—Query List ANQP-element format 713
Figure 8-405—Capability List ANQP-element format 713
Figure 8-406—Venue Name ANQP-element format 714
Figure 8-407—Venue Name Duple field 714
Figure 8-408—Emergency Call Number ANQP-element format 715
Figure 8-409—Emergency Call Number Unit field format 715
Figure 8-410—Network Authentication Type ANQP-element format 715
Figure 8-411—Network Authentication Type Unit field format 716
Figure 8-412—Roaming Consortium ANQP-element format 717
Figure 8-413—OI Duple field format 717
Figure 8-414—Vendor Specific ANQP-element format 717
Figure 8-415—IP Address Type Availability ANQP-element 718
Figure 8-416—IP Address field format 718
Figure 8-417—NAI Realm ANQP-element format 719
Figure 8-418—NAI Realm Data field format 719
Figure 8-419—NAI Realm Encoding subfield format 720
Figure 8-420—EAP Method subfield format 720
Figure 8-421—Authentication Parameter subfield format 721
Figure 8-422—3GPP Cellular Network ANQP-element format 722
Figure 8-423—AP Geospatial Location ANQP-element format 723
Figure 8-424—AP Civic Location ANQP-element format 723
Figure 8-425—AP Location Public Identifier URI ANQP-element format 724
Figure 8-426—Domain Name ANQP-element format 724
Figure 8-427—Domain Name subfield format 724
Figure 8-428—Emergency Alert URI ANQP-element format 725
Figure 8-429—Emergency NAI ANQP-element format 725
Figure 8-430—TDLS Capability ANQP-element format 725

Figure 8-431—Neighbor Report ANQP-element format 726
Figure 8-432—Measurement Request frame Action field format 727
Figure 8-433—Measurement Report frame Action field format 727
Figure 8-434—TPC Request frame Action field format 728
Figure 8-435—TPC Report frame Action field format 728
Figure 8-436—Channel Switch Announcement frame Action field format 729
Figure 8-437—Vendor Specific Action frame Action field format 737
Figure 8-438—Radio Measurement Request frame Action field format 738
Figure 8-439—Radio Measurement Report frame Action field format 739
Figure 8-440—Link Measurement Request frame Action field format 739
Figure 8-441—Link Measurement Report frame Action field format 741
Figure 8-442—Neighbor Report Request frame Action field format 742
Figure 8-443—Neighbor Report Response frame Action field format 743
Figure 8-445—Condensed Capability Information field 745
Figure 8-444—Measurement Pilot frame Action field format 745
Figure 8-446—DSE Enablement frame Action field format 746
Figure 8-447—DSE Deenablement frame Action field format 747
Figure 8-448—DSE Registered Location Announcement frame Action field format 748
Figure 8-449—Extended Channel Switch Announcement frame Action field format 748
Figure 8-451—DSE Measurement Report frame Action field format 749
Figure 8-450—DSE Measurement Request frame Action field format 749
Figure 8-452—DSE LCI field format 750
Figure 8-453—DSE Power Constraint frame Action field format 751
Figure 8-454—Vendor Specific Public Action frame Action field format 752
Figure 8-455—Query Request length field 753
Figure 8-456—Query Request field 753
Figure 8-457—GAS Comeback Delay field 754
Figure 8-458—Query Response length field 754
Figure 8-459—Query Response field 754
Figure 8-460—Location Track Notification frame format 757
Figure 8-461—FT Request frame Action field format 759
Figure 8-462—FT Response frame Action field format 759
Figure 8-463—FT Confirm frame Action field format 760
Figure 8-464—FT Ack frame Action field format 761
Figure 8-465—SA Query Request frame Action field format 762
Figure 8-466—SA Query Response frame Action field format 762
Figure 8-467—Event Request frame body format 777
Figure 8-468—Event Report frame body format 777
Figure 8-469—Diagnostic Request frame body format 778
Figure 8-470—Diagnostic Report frame body format 778
Figure 8-472—Location Configuration Response frame body format 779
Figure 8-471—Location Configuration Request frame body format 779
Figure 8-473—BSS Transition Management Query frame body format 780
Figure 8-474—BSS Transition Management Request frame body format 781
Figure 8-475—Request Mode field 782
Figure 8-476—Disassociation Timer field format 782
Figure 8-477—Session Information URL field format 783
Figure 8-478— BSS Transition Management Response frame body format 783
Figure 8-479—FMS Request frame format 784
Figure 8-480—FMS Response frame format 785
Figure 8-481—Collocated Interference Request frame format 785
Figure 8-482—Request Info field format 786
Figure 8-483—Collocated Interference Report frame format 786
Figure 8-484—TFS Request frame format 787

Figure 8-485—TFS Response frame format 787
Figure 8-486—TFS Notify frame format 788
Figure 8-487—WNM-Sleep Mode Request frame format 788
Figure 8-488—WNM-Sleep Mode Response frame format 789
Figure 8-489—WNM-Sleep Mode GTK subelement format 790
Figure 8-490—WNM-Sleep Mode IGTK subelement format 790
Figure 8-491—TIM Broadcast Request frame format 791
Figure 8-492—TIM Broadcast Response frame format 791
Figure 8-494—Channel Usage Request frame format 792
Figure 8-493—QoS Traffic Capability Update frame format 792
Figure 8-495—Channel Usage Response frame format 793
Figure 8-496—DMS Request frame format 793
Figure 8-497—DMS Response frame format 794
Figure 8-498—Timing Measurement Request frame format 794
Figure 8-499—WNM-Notification Request frame format 795
Figure 8-500—WNM-Notification Response frame format 796
Figure 8-501—TIM frame format 797
Figure 8-502—Timing Measurement frame format 798
Figure 8-503—A-MPDU format 812
Figure 8-504—A-MPDU subframe format 812
Figure 8-505—MPDU delimiter 813
Figure 8-506—MPDU delimiter CRC calculation 814
Figure 9-1—MAC architecture 818
Figure 9-2—Fragmentation 823
Figure 9-3—Some IFS relationships 826
Figure 9-4—RTS/CTS/data/ACK and NAV setting 829
Figure 9-5—RTS/CTS with fragmented MSDU 830
Figure 9-6—RTS/CTS with transmitter priority and missed acknowledgment 830
Figure 9-7—Example of dual CTS mechanism (STBC initiator) 833
Figure 9-8—Example of the dual CTS mechanism (non-STBC initiator) 833
Figure 9-9—Individually addressed data/ACK MPDU 834
Figure 9-10—Example of exponential increase of CW 837
Figure 9-11—Basic access method 838
Figure 9-12—Backoff procedure 839
Figure 9-13—Transmission of a multiple-fragment MSDU using SIFS 841
Figure 9-14—DCF timing relationships 843
Figure 9-15—CFP/CP alternation 846
Figure 9-16—Beacon frames and CFPs 846
Figure 9-17—Example of delayed beacon and shortened CFP 847
Figure 9-18—Example of PCF frame transfer 848
Figure 9-19—Reference implementation model 874
Figure 9-20—EDCA mechanism timing relationships 877
Figure 9-21—Example of TXOP truncation 881
Figure 9-22—CAP/CFP/CP periods 882
Figure 9-23—Polled TXOP 885
Figure 9-24—Example MCCAOP reservation with MCCAOP Periodicity equal to 2 894
Figure 9-25—Message sequence chart for Block Ack mechanism: (a) setup, (b) data and acknowledgment transfer and (c) tear down 904
Figure 9-26—A typical Block Ack sequence when immediate policy is used 907
Figure 9-27—A typical BlockAck sequence when delayed policy is used 907
Figure 9-28—HT-immediate Block Ack architecture 910
Figure 9-29—Basic concept of L-SIG TXOP protection 926
Figure 9-30—Example of L-SIG duration setting 927
Figure 9-31—Illustration of PSMP sequence with and without PSMP recovery 936

Figure 9-32—PSMP burst 937
Figure 9-33—PSMP burst showing resource allocation 938
Figure 9-34—PSMP burst showing retransmission and resource allocation 939
Figure 9-35—Example PPDU exchange for unidirectional implicit transmit beamforming 948
Figure 9-36—Example PPDU exchange for bidirectional implicit transmit beamforming 949
Figure 9-37—Calibration procedure with sounding PPDU containing an MPDU 951
Figure 9-38—Calibration procedure with NDP 952
Figure 9-39—Calibration procedure with NDP when STA B supports transmitting sounding PPDUs for which only one channel dimension can be estimated (i.e., a single column of the MIMO channel matrix) 953
Figure 9-40—Transmit ASEL 959
Figure 9-41—Receive ASEL 961
Figure 9-42—Example addressing for a Mesh Data frame 966
Figure 10-1—Beacon transmission on a busy network 974
Figure 10-2—Beacon transmission in an IBSS 975
Figure 10-3—Probe response 980
Figure 10-4—Infrastructure power management operation (no PCF operating) 986
Figure 10-5—Power management in an IBSS—basic operation 1007
Figure 10-6—Relationship between state and services 1012
Figure 10-7—TS life cycle 1025
Figure 10-8—TS setup 1026
Figure 10-9—Failed TS setup detected within non-AP STA's MLME 1030
Figure 10-10—TS deletion 1031
Figure 10-11—TS timeout 1033
Figure 10-12—Block Ack setup 1034
Figure 10-13—Block Ack deletion 1035
Figure 10-14—Error recovery by the receiver upon a peer failure 1037
Figure 10-15—The four steps involved in direct-link handshake 1039
Figure 10-16—DLS message flow 1040
Figure 10-17—STA-initiated DLS teardown message flow 1042
Figure 10-18—Example of Measurement Pilot Scheduling 1081
Figure 10-19—Dependent STA state machine 1088
Figure 10-20—Phased coexistence operation (PCO) 1104
Figure 10-21—Events occurring for a TDLS direct-link channel switch 1115
Figure 10-22—STA transmission on three channels, three frames per channel with Normal Report Interval 1128
Figure 10-23—Timing measurement procedure 1131
Figure 10-24—GAS message sequence with dot11GASPauseForServerResponse equal to true 1146
Figure 10-25—GAS message sequence with GAS fragmentation and dot11GASPauseForServerResponse equal to true 1147
Figure 10-26—GAS message sequence with GAS fragmentation and dot11GASPauseForServerResponse equal to false 1148
Figure 10-27—Example TDLS Capability discovery using ANQP 1156
Figure 11-1—Construction of expanded WEP MPDU 1167
Figure 11-2—WEP encapsulation block diagram 1169
Figure 11-3—WEP decapsulation block diagram 1170
Figure 11-4—SAE finite state machine 1185
Figure 11-5—TKIP encapsulation block diagram 1192
Figure 11-6—TKIP decapsulation block diagram 1193
Figure 11-7—Construction of expanded TKIP MPDU 1194
Figure 11-8—TKIP MIC relation to IEEE 802.11 processing (informative) 1195
Figure 11-9—TKIP MIC processing format 1196
Figure 11-10—Michael message processing 1197
Figure 11-11—Michael block function 1197

Figure 11-12—Authenticator MIC countermeasures 1199
Figure 11-13—Supplicant MIC countermeasures 1200
Figure 11-14—Phase 1 key mixing 1203
Figure 11-15—Phase 2 key mixing 1204
Figure 11-16—Expanded CCMP MPDU 1206
Figure 11-17—CCMP encapsulation block diagram 1207
Figure 11-18—AAD construction 1208
Figure 11-19—Nonce construction 1209
Figure 11-20—Nonce Flags subfield 1209
Figure 11-21—CCMP decapsulation block diagram 1210
Figure 11-22—BIP Encapsulation 1212
Figure 11-23—BIP AAD Construction 1213
Figure 11-24—Pairwise key hierarchy 1236
Figure 11-25—Group key hierarchy (informative) 1238
Figure 11-26—PeerKey hierarchy 1239
Figure 11-27—FT key hierarchy at an Authenticator 1241
Figure 11-28—EAPOL-Key frame 1245
Figure 11-29—Key Information bit layout 1245
Figure 11-30—KDE format 1249
Figure 11-31—GTK KDE format 1250
Figure 11-32—MAC address KDE format 1250
Figure 11-33—PMKID KDE format 1250
Figure 11-34—SMK KDE format 1250
Figure 11-35—Nonce KDE format 1250
Figure 11-36—Lifetime KDE format 1250
Figure 11-37—Error KDE format 1251
Figure 11-38—IGTK KDE format 1251
Figure 11-39—Key ID KDE 1252
Figure 11-40—Sample 4-Way Handshake 1262
Figure 11-41—Sample Group Key Handshake 1267
Figure 11-42—PeerKey Handshake Supplicant key management state machine 1285
Figure 11-43—RSNA Supplicant key management state machine 1287
Figure 11-44—Authenticator state machines, part 1 1290
Figure 11-45—Authenticator state machines, part 2 1291
Figure 11-46—Authenticator state machines, part 3 1291
Figure 11-47—Authenticator state machines, part 4 1292
Figure 12-1—FT key holder architecture 1309
Figure 12-2—FT initial mobility domain association in an RSN 1312
Figure 12-3—FT initial mobility domain association in a non-RSN 1314
Figure 12-4—Over-the-air FT Protocol in an RSN 1315
Figure 12-5—Over-the-DS FT Protocol in an RSN 1317
Figure 12-6—MLME interfaces for over-the-DS FT Protocol messages 1318
Figure 12-7—Over-the-air FT Protocol in a non-RSN 1319
Figure 12-8—Over-the-DS FT Protocol in a non-RSN 1320
Figure 12-9—Over-the-air FT Resource Request Protocol in an RSN 1321
Figure 12-10—Over-the-air FT Resource Request Protocol in a non-RSN 1322
Figure 12-11—Over-the-DS FT Resource Request Protocol in an RSN 1324
Figure 12-12—Over-the-DS FT Resource Request Protocol in a non-RSN 1324
Figure 12-13—R0KH state machine 1333
Figure 12-14—R1KH state machine, including portions of the SME (part 1) 1335
Figure 12-15—R1KH state machine, including portions of the SME (part 2) 1336
Figure 12-16—S0KH state machine 1338
Figure 12-17—S1KH state machine, including portions of the SME (part 1) 1340
Figure 12-18—S1KH state machine, including portions of the SME (part 2) 1341

Figure 12-19—Sample message flow for over-the-DS resource request 1345
Figure 12-20—RIC-Request format 1346
Figure 12-21—Resource Request format 1346
Figure 12-22—Resource Request example #1 1347
Figure 12-23—Resource Request example #2 1347
Figure 12-24—RIC-Request example #1 1347
Figure 12-25—RIC-Request example #2 1347
Figure 12-26—RIC-Request example #3 1348
Figure 12-27—RIC-Response format 1348
Figure 12-28—Example QoS RIC-Response 1348
Figure 12-29—Overview of RIC processing at an AP 1350
Figure 13-1—Logical flowchart of protocol interaction in the mesh peering management framework 1356
Figure 13-2—Finite state machine of the MPM protocol 1365
Figure 13-3—Finite state machine of the AMPE protocol 1376
Figure 13-4—Illustration of definitions 1383
Figure 13-5—An example of mesh power mode usage 1433
Figure 13-6—Mesh power management operation 1437
Figure 13-7—Mesh peer service period 1439
Figure 14-1—State diagram notation example 1445
Figure 14-2—PLCP frame format 1446
Figure 14-3—Frame synchronous scrambler/descrambler 1448
Figure 14-4—PLCP data whitener format 1448
Figure 14-5—PLCP top-level state diagram 1449
Figure 14-6—Transmit state machine 1450
Figure 14-7—Data whitener encoding procedure 1451
Figure 14-8—Transmit state timing 1453
Figure 14-9—CS/CCA state machine 1454
Figure 14-10—CS/CCA state timing 1456
Figure 14-11—Receive state machine 1457
Figure 14-12—Data whitener decoding procedure 1457
Figure 14-13—Receive timing 1459
Figure 14-14—PLME state machine 1460
Figure 14-15—PMD layer reference model 1461
Figure 14-16—Transmit modulation mask 1474
Figure 14-17—4GFSK transmit modulation 1479
Figure 15-1—PPDU frame format 1491
Figure 15-2—Basic pulse shape 1497
Figure 15-3—Emitter radiation pattern Mask 1 1498
Figure 15-4—Emitter radiation pattern Mask 2 1499
Figure 15-5—Mask 2 device orientation drawing 1499
Figure 15-6—Transmit spectrum mask 1500
Figure 16-1—PLCP frame format 1505
Figure 16-2—CRC-16 implementation 1507
Figure 16-3—Example CRC calculation 1507
Figure 16-4—Data scrambler 1508
Figure 16-5—Data descrambler 1508
Figure 16-6—Transmit PLCP 1509
Figure 16-7—PLCP transmit state machine 1510
Figure 16-8—Receive PLCP 1510
Figure 16-9—PLCP receive state machine 1512
Figure 16-10—PMD layer reference model 1515
Figure 16-11—Transmit spectrum mask 1530
Figure 16-12—Transmit power-on ramp 1530
Figure 16-13—Transmit power-down ramp 1531

Figure 16-14—Modulation accuracy measurement example 1531
Figure 16-15—Chip clock alignment with baseband eye pattern 1532
Figure 17-1—Long PPDU format 1538
Figure 17-2—Short PPDU format 1539
Figure 17-3—CRC-16 implementation 1543
Figure 17-4—Example of CRC calculation 1544
Figure 17-5—Data scrambler 1545
Figure 17-6—Data descrambler 1546
Figure 17-7—Transmit PLCP 1547
Figure 17-8—Receive PLCP 1549
Figure 17-9—PLCP receive state machine 1550
Figure 17-10—Layer reference model 1555
Figure 17-11—PBCC modulator scheme 1570
Figure 17-12—PBCC convolutional encoder 1570
Figure 17-13—Cover code mapping 1571
Figure 17-14—China and North American channel selection—nonoverlapping 1572
Figure 17-15—China and North American channel selection—overlapping 1573
Figure 17-16—European channel selection—nonoverlapping 1573
Figure 17-17—European channel selection—overlapping 1573
Figure 17-18—Transmit spectrum mask 1576
Figure 17-19—Transmit power-on ramp 1577
Figure 17-20—Transmit power-down ramp 1577
Figure 17-21—Modulation accuracy measurement example 1578
Figure 17-22—Chip clock alignment with baseband eye pattern 1579
Figure 18-1—PPDU frame format 1588
Figure 18-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period 1592
Figure 18-3—Inputs and outputs of inverse Fourier transform 1593
Figure 18-4—OFDM training structure 1593
Figure 18-5—SIGNAL field bit assignment 1595
Figure 18-6—SERVICE field bit assignment 1596
Figure 18-7—Data scrambler 1597
Figure 18-8—Convolutional encoder (k = 7) 1598
Figure 18-9—Example of the bit-stealing and bit-insertion procedure (r = 3/4, 2/3) 1599
Figure 18-10—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding 1601
Figure 18-11—Subcarrier frequency allocation 1604
Figure 18-12—Transmitter and receiver block diagram for the OFDM PHY 1605
Figure 18-13—Transmit spectrum mask for 20 MHz transmission 1608
Figure 18-14—Transmit spectrum mask for 10 MHz transmission 1608
Figure 18-15—Transmit spectrum mask for 5 MHz transmission 1609
Figure 18-16—Constellation error 1611
Figure 18-17—Transmit PLCP 1615
Figure 18-18—PLCP transmit state machine 1617
Figure 18-19—Receive PLCP 1618
Figure 18-20—PLCP receive state machine 1620
Figure 18-21—PMD layer reference model 1624
Figure 19-1—Long preamble PPDU format for DSSS-OFDM 1639
Figure 19-2—Short preamble PPDU format for DSSS-OFDM 1640
Figure 19-3—22/33 Mb/s ERP-PBCC convolutional encoder 1641
Figure 19-4—ERP-PBCC-22 and ERP-PBCC-33 cover code mapping 1642
Figure 19-5—33 Mb/s clock switching 1642
Figure 19-6—DSSS-OFDM PSDU 1643
Figure 19-7—Single carrier to multicarrier transition definition 1649
Figure 19-8—Linear distortions common to the single carrier and multicarrier signal segments 1650

Figure 19-9—Spectral shaping achieved by OFDM symbol onset and termination shaping 1651
Figure 19-10—Subcarrier spectrums for rectangular windowing and Clause 18 suggested windowing 1652
Figure 19-11—Foundational brickwall filter 1653
Figure 19-12—Continuous time Hanning window 1654
Figure 19-13—Specified pulse 1654
Figure 19-14—Single carrier frequency response 1655
Figure 19-15—Comparing signal power 1655
Figure 19-16—Aligning the 11 MHz and 20 MHz clocks 1656
Figure 19-17—Single carrier to OFDM time alignment 1656
Figure 19-18—Single carrier termination requirement 1657
Figure 19-19—Carrier frequency coherency shall be maintained 1657
Figure 19-20—The phase of the first OFDM segment symbol is established by the last Barker symbol 1658
Figure 19-21—BPSK and QPSK signaling with the I/Q channels maximally energized 1658
Figure 20-1—PPDU format 1682
Figure 20-2—Transmitter block diagram 1 1685
Figure 20-3—Transmitter block diagram 2 1685
Figure 20-4—Timing boundaries for PPDU fields 1691
Figure 20-5—L-SIG structure 1697
Figure 20-6—Format of HT-SIG1 and HT-SIG2 1700
Figure 20-7—Data tone constellations in an HT-mixed format PPDU 1701
Figure 20-8—HT-SIG CRC calculation 1702
Figure 20-9—Generation of HT-DLTFs 1705
Figure 20-10—Generation of HT-ELTFs 1706
Figure 20-11—Puncturing at rate 5/6 1712
Figure 20-12—Examples of cyclic-permutation matrices with Z=8 1713
Figure 20-13—LDPC PPDU encoding padding and puncturing of a single codeword 1716
Figure 20-14—Beamforming MIMO channel model (3x2 example) 1728
Figure 20-15—Baseband-to-baseband channel 1729
Figure 20-16—Example of an NDP used for sounding 1735
Figure 20-17—Transmit spectral mask for 20 MHz transmission in the 2.4 GHz band 1739
Figure 20-18—Transmit spectral mask for a 40 MHz channel in the 2.4 GHz band 1740
Figure 20-19—Transmit spectral mask for 20 MHz transmission in the 5 GHz band 1740
Figure 20-20—Transmit spectral mask for a 40 MHz channel in the 5 GHz band 1740
Figure 20-21—Packet alignment example (HT-greenfield format packet with short GI) 1742
Figure 20-22—PLCP transmit procedure (HT-mixed format PPDU) 1748
Figure 20-23—PLCP transmit procedure (HT-greenfield format PPDU) 1749
Figure 20-24—PLCP transmit state machine 1751
Figure 20-25—PLCP receive procedure for HT-mixed format PLCP format 1752
Figure 20-26—PLCP receive procedure for HT-greenfield format PLCP 1753
Figure 20-27—PLCP receive state machine 1754
Figure 20-28—PMD layer reference model 1762
Figure D-1—Transmit spectrum mask and application 2291
Figure H-1—Ethertype 89-0d frame body 2320
Figure M-1—Randomness generating circuit 2618
Figure N-1—Schedule for stream from STA i 2633
Figure N-2—Schedule for streams from STAs i to k 2634
Figure N-3—Reallocation of TXOPs when a stream is dropped 2634
Figure O-1—Virtual bitmap example #1 2636
Figure O-2—Virtual bitmap example #2 2637
Figure O-3—Virtual bitmap example #3 2637
Figure O-4—Virtual Bitmap Example #4, Method A and Method B 2637
Figure O-5—Virtual Bitmap Example #5, Method A or Method B 2638

Figure O-6—Virtual Bitmap Example #5, Method A 2638
Figure O-7—Virtual Example #5, Method B 2639
Figure Q-1—Very high level UML use case diagram for the AP 2650
Figure Q-2—Very high level UML use case diagram for the WLAN system 2650
Figure Q-3—High-level UML use case diagram for the WLAN system 2651
Figure Q-4—High-level UML entity diagram for the WLAN system 2652
Figure Q-5—AP UML composition diagram (alternate syntax) 2653
Figure Q-6—High-level UML use case diagram for the AP 2654
Figure R-1—Location of the DS SAP 2656
Figure S-1—A-MPDU parsing 2661
Figure S-2—Example of RD exchange sequence showing response burst 2662
Figure S-3—Determination of NDP source and destination for unidirectional NDP sequences 2663
Figure S-4—Determination of NDP source and destination for bidirectional NDP sequence 2664
Figure V-1—Interworking IEEE 802.11 infrastructure supporting multiple SSPNs 2677
Figure V-2—Basic architecture of the interworking service 2680
Figure W-1—Format of a CCMP-encrypted Mesh Data frame containing a single MSDU 2688