

ISO/IEC/IEEE 8802-15-4:2010-10 (E)

Information technology_ - Telecommunications and information exchange between systems_ - Local and metropolitan area networks_ - Specific requirements

Contents

- 1. Overview..... 1
 - 1.1 General..... 1
 - 1.2 Scope..... 1
 - 1.3 Purpose..... 2
- 2. Normative references 3
- 3. Definitions 5
- 4. Acronyms and abbreviations 9
- 5. General description 13
 - 5.1 Introduction..... 13
 - 5.2 Components of the IEEE 802.15.4 WPAN..... 13
 - 5.3 Network topologies..... 14
 - 5.3.1 Star network formation 14
 - 5.3.2 Peer-to-peer network formation 15
 - 5.4 Architecture 15
 - 5.4.1 Physical layer (PHY) 17
 - 5.4.2 MAC sublayer..... 17
 - 5.5 Functional overview 17
 - 5.5.1 Superframe structure..... 17
 - 5.5.2 Data transfer model..... 18
 - 5.5.2.1 Data transfer to a coordinator 19
 - 5.5.2.2 Data transfer from a coordinator..... 20
 - 5.5.2.3 Peer-to-peer data transfers 21
 - 5.5.3 Frame structure 21
 - 5.5.3.1 Beacon frame 21
 - 5.5.3.2 Data frame..... 22
 - 5.5.3.3 Acknowledgment frame..... 22
 - 5.5.3.4 MAC command frame 23
 - 5.5.4 Improving probability of successful delivery 23
 - 5.5.4.1 CSMA-CA mechanism 23
 - 5.5.4.2 Frame acknowledgment..... 24
 - 5.5.4.3 Data verification 24
 - 5.5.5 Power consumption considerations 24
 - 5.5.6 Security 24
 - 5.6 Concept of primitives..... 25
- 6. PHY specification 27
 - 6.1 General requirements and definitions 27
 - 6.1.1 Operating frequency range..... 27
 - 6.1.2 Channel assignments..... 28
 - 6.1.2.1 Channel numbering..... 29
 - 6.1.2.2 Channel pages..... 29
 - 6.1.3 Minimum long interframe spacing (LIFS) and short interframe spacing (SIFS) periods 30

6.1.4	RF power measurement	31
6.1.5	Transmit power	31
6.1.6	Out-of-band spurious emission	31
6.1.7	Receiver sensitivity definitions	31
6.2	PHY service specifications	31
6.2.1	PHY data service	32
6.2.1.1	PD-DATA.request	32
6.2.1.2	PD-DATA.confirm	33
6.2.1.3	PD-DATA.indication	34
6.2.2	PHY management service.....	34
6.2.2.1	PLME-CCA.request.....	35
6.2.2.2	PLME-CCA.confirm.....	35
6.2.2.3	PLME-ED.request.....	36
6.2.2.4	PLME-ED.confirm	36
6.2.2.5	PLME-GET.request	37
6.2.2.6	PLME-GET.confirm	38
6.2.2.7	PLME-SET-TRX-STATE.request.....	39
6.2.2.8	PLME-SET-TRX-STATE.confirm.....	40
6.2.2.9	PLME-SET.request.....	40
6.2.2.10	PLME-SET.confirm.....	41
6.2.3	PHY enumerations description	42
6.3	PPDU format.....	43
6.3.1	Preamble field	43
6.3.2	SFD field.....	44
6.3.3	Frame Length field.....	45
6.3.4	PSDU field.....	45
6.4	PHY constants and PIB attributes.....	45
6.4.1	PHY constants.....	45
6.4.2	PHY PIB attributes	45
6.5	2450 MHz PHY specifications	47
6.5.1	Data rate	47
6.5.2	Modulation and spreading	47
6.5.2.1	Reference modulator diagram.....	47
6.5.2.2	Bit-to-symbol mapping	47
6.5.2.3	Symbol-to-chip mapping	47
6.5.2.4	O-QPSK modulation.....	48
6.5.2.5	Pulse shape.....	49
6.5.2.6	Chip transmission order	49
6.5.3	2450 MHz band radio specification.....	49
6.5.3.1	Transmit power spectral density (PSD) mask.....	49
6.5.3.2	Symbol rate	49
6.5.3.3	Receiver sensitivity.....	49
6.5.3.4	Receiver jamming resistance	50
6.6	868/915 MHz band binary phase-shift keying (BPSK) PHY specifications	50
6.6.1	868/915 MHz band data rates	50
6.6.2	Modulation and spreading	50
6.6.2.1	Reference modulator diagram.....	50
6.6.2.2	Differential encoding	51
6.6.2.3	Bit-to-chip mapping	51
6.6.2.4	BPSK modulation	51
6.6.3	868/915 MHz band radio specification.....	52
6.6.3.1	Operating frequency range.....	52
6.6.3.2	915 MHz band transmit PSD mask.....	52
6.6.3.3	Symbol rate	52

6.6.3.4	Receiver sensitivity	52
6.6.3.5	Receiver jamming resistance	52
6.7	868/915 MHz band (optional) amplitude shift keying (ASK) PHY specifications	53
6.7.1	868/915 MHz band data rates	53
6.7.2	Modulation and spreading	53
6.7.2.1	Reference modulator diagram.....	53
6.7.2.2	Bit-to-symbol mapping	54
6.7.2.3	Symbol-to-chip mapping	54
6.7.2.4	ASK modulation	55
6.7.3	868/915 MHz band radio specification for the ASK PHY	57
6.7.3.1	Operating frequency range.....	57
6.7.3.2	915 MHz band transmit PSD mask.....	57
6.7.3.3	Symbol rate	57
6.7.3.4	Receiver sensitivity	57
6.7.3.5	Receiver jamming resistance	57
6.7.4	SHR for ASK PHY	58
6.7.4.1	Preamble for ASK PHY	58
6.7.4.2	SFD for ASK PHY	58
6.7.4.3	Example of PSSS encoding	58
6.8	868/915 MHz band (optional) O-QPSK PHY specifications	60
6.8.1	868/915 MHz band data rates	60
6.8.2	Modulation and spreading	60
6.8.2.1	Reference modulator diagram.....	60
6.8.2.2	Bit-to-symbol mapping	60
6.8.2.3	Symbol-to-chip mapping	60
6.8.2.4	O-QPSK modulation.....	61
6.8.2.5	Pulse shape.....	62
6.8.2.6	Chip transmission order	62
6.8.3	868/915 MHz band radio specification.....	62
6.8.3.1	Operating frequency range.....	62
6.8.3.2	Transmit PSD mask	62
6.8.3.3	Symbol rate	63
6.8.3.4	Receiver sensitivity	63
6.8.3.5	Receiver jamming resistance	63
6.9	General radio specifications.....	63
6.9.1	TX-to-RX turnaround time	63
6.9.2	RX-to-TX turnaround time	64
6.9.3	Error-vector magnitude (EVM) definition.....	64
6.9.4	Transmit center frequency tolerance.....	65
6.9.5	Transmit power	65
6.9.6	Receiver maximum input level of desired signal.....	65
6.9.7	Receiver ED	65
6.9.8	Link quality indicator (LQI)	65
6.9.9	Clear channel assessment (CCA).....	66
7.	MAC sublayer specification	67
7.1	MAC sublayer service specification	67
7.1.1	MAC data service	68
7.1.1.1	MCPS-DATA.request.....	68
7.1.1.2	MCPS-DATA.confirm.....	71
7.1.1.3	MCPS-DATA.indication	72
7.1.1.4	MCPS-PURGE.request	75
7.1.1.5	MCPS-PURGE.confirm.....	75

7.1.1.6	Data service message sequence chart	76
7.1.2	MAC management service.....	76
7.1.3	Association primitives	77
7.1.3.1	MLME-ASSOCIATE.request.....	78
7.1.3.2	MLME-ASSOCIATE.indication	80
7.1.3.3	MLME-ASSOCIATE.response	81
7.1.3.4	MLME-ASSOCIATE.confirm	83
7.1.3.5	Association message sequence charts.....	85
7.1.4	Disassociation primitives.....	86
7.1.4.1	MLME-DISASSOCIATE.request	86
7.1.4.2	MLME-DISASSOCIATE.indication.....	89
7.1.4.3	MLME-DISASSOCIATE.confirm	90
7.1.4.4	Disassociation message sequence charts	91
7.1.5	Beacon notification primitive	92
7.1.5.1	MLME-BEACON-NOTIFY.indication.....	92
7.1.6	Primitives for reading PIB attributes	94
7.1.6.1	MLME-GET.request.....	95
7.1.6.2	MLME-GET.confirm.....	96
7.1.7	GTS management primitives	97
7.1.7.1	MLME-GTS.request	97
7.1.7.2	MLME-GTS.confirm.....	99
7.1.7.3	MLME-GTS.indication.....	100
7.1.7.4	GTS management message sequence charts.....	102
7.1.8	Primitives for orphan notification	103
7.1.8.1	MLME-ORPHAN.indication.....	103
7.1.8.2	MLME-ORPHAN.response.....	104
7.1.8.3	Orphan notification message sequence chart.....	106
7.1.9	Primitives for resetting the MAC sublayer.....	106
7.1.9.1	MLME-RESET.request	106
7.1.9.2	MLME-RESET.confirm	107
7.1.10	Primitives for specifying the receiver enable time	108
7.1.10.1	MLME-RX-ENABLE.request	108
7.1.10.2	MLME-RX-ENABLE.confirm.....	110
7.1.10.3	Message sequence chart for changing the state of the receiver	110
7.1.11	Primitives for channel scanning.....	111
7.1.11.1	MLME-SCAN.request.....	111
7.1.11.2	MLME-SCAN.confirm.....	114
7.1.11.3	Channel scan message sequence charts	116
7.1.12	Communication status primitive.....	116
7.1.12.1	MLME-COMM-STATUS.indication.....	116
7.1.13	Primitives for writing PIB attributes.....	119
7.1.13.1	MLME-SET.request	119
7.1.13.2	MLME-SET.confirm	121
7.1.14	Primitives for updating the superframe configuration.....	122
7.1.14.1	MLME-START.request.....	122
7.1.14.2	MLME-START.confirm.....	126
7.1.14.3	Message sequence chart for updating the superframe configuration.....	126
7.1.15	Primitives for synchronizing with a coordinator	127
7.1.15.1	MLME-SYNC.request.....	127
7.1.15.2	MLME-SYNC-LOSS.indication	128
7.1.15.3	Message sequence chart for synchronizing with a coordinator	131
7.1.16	Primitives for requesting data from a coordinator	131
7.1.16.1	MLME-POLL.request.....	132
7.1.16.2	MLME-POLL.confirm	133

7.1.16.3	Message sequence chart for requesting data from a coordinator	134
7.1.17	MAC enumeration description.....	135
7.2	MAC frame formats.....	137
7.2.1	General MAC frame format.....	138
7.2.1.1	Frame Control field.....	138
7.2.1.2	Sequence Number field.....	140
7.2.1.3	Destination PAN Identifier field.....	140
7.2.1.4	Destination Address field.....	140
7.2.1.5	Source PAN Identifier field	141
7.2.1.6	Source Address field.....	141
7.2.1.7	Auxiliary Security Header field.....	141
7.2.1.8	Frame Payload field.....	141
7.2.1.9	FCS field.....	141
7.2.2	Format of individual frame types.....	142
7.2.2.1	Beacon frame format	142
7.2.2.2	Data frame format.....	146
7.2.2.3	Acknowledgment frame format	147
7.2.2.4	MAC command frame format.....	147
7.2.3	Frame compatibility.....	148
7.3	MAC command frames.....	149
7.3.1	Association request command	150
7.3.1.1	MHR fields	150
7.3.1.2	Capability Information field	150
7.3.2	Association response command.....	151
7.3.2.1	MHR fields	151
7.3.2.2	Short Address field	152
7.3.2.3	Association Status field	152
7.3.3	Disassociation notification command.....	152
7.3.3.1	MHR fields	153
7.3.3.2	Disassociation Reason field.....	153
7.3.4	Data request command.....	153
7.3.5	PAN ID conflict notification command.....	154
7.3.6	Orphan notification command	155
7.3.7	Beacon request command	156
7.3.8	Coordinator realignment command	156
7.3.8.1	MHR fields	157
7.3.8.2	PAN Identifier field	157
7.3.8.3	Coordinator Short Address field.....	157
7.3.8.4	Logical Channel field.....	157
7.3.8.5	Short Address field	157
7.3.8.6	Channel Page field.....	157
7.3.9	GTS request command.....	158
7.3.9.1	MHR fields	158
7.3.9.2	GTS Characteristics field.....	158
7.4	MAC constants and PIB attributes.....	159
7.4.1	MAC constants	159
7.4.2	MAC PIB attributes	160
7.5	MAC functional description	166
7.5.1	Channel access.....	167
7.5.1.1	Superframe structure.....	167
7.5.1.2	Incoming and outgoing superframe timing.....	169
7.5.1.3	Interframe spacing (IFS).....	169
7.5.1.4	CSMA-CA algorithm.....	170
7.5.2	Starting and maintaining PANs	172

7.5.2.1	Scanning through channels	172
7.5.2.2	PAN identifier conflict resolution.....	176
7.5.2.3	Starting and realigning a PAN.....	177
7.5.2.4	Beacon generation.....	178
7.5.2.5	Device discovery.....	179
7.5.3	Association and disassociation	179
7.5.3.1	Association.....	179
7.5.3.2	Disassociation	181
7.5.4	Synchronization	182
7.5.4.1	Synchronization with beacons	182
7.5.4.2	Synchronization without beacons	183
7.5.4.3	Orphaned device realignment	183
7.5.5	Transaction handling.....	183
7.5.6	Transmission, reception, and acknowledgment.....	185
7.5.6.1	Transmission.....	185
7.5.6.2	Reception and rejection	186
7.5.6.3	Extracting pending data from a coordinator	187
7.5.6.4	Use of acknowledgments and retransmissions	189
7.5.6.5	Promiscuous mode.....	190
7.5.6.6	Transmission scenarios	191
7.5.7	GTS allocation and management.....	192
7.5.7.1	CAP maintenance	193
7.5.7.2	GTS allocation	193
7.5.7.3	GTS usage.....	194
7.5.7.4	GTS deallocation	195
7.5.7.5	GTS reallocation	196
7.5.7.6	GTS expiration.....	197
7.5.8	Frame security.....	197
7.5.8.1	Security-related MAC PIB attributes.....	197
7.5.8.2	Functional description.....	199
7.6	Security suite specifications.....	206
7.6.1	PIB security material	206
7.6.2	Auxiliary security header.....	210
7.6.2.1	Integer and octet representation	210
7.6.2.2	Security Control field.....	210
7.6.2.3	Frame Counter field.....	212
7.6.2.4	Key Identifier field.....	212
7.6.3	Security operations	213
7.6.3.1	Integer and octet representation	213
7.6.3.2	CCM* Nonce	213
7.6.3.3	CCM* prerequisites	213
7.6.3.4	CCM* transformation data representation.....	214
7.6.3.5	CCM* inverse transformation data representation	215
7.7	Message sequence charts illustrating MAC-PHY interaction	216
Annex A (normative) Service-specific convergence sublayer (SSCS).....		227
A.1	IEEE 802.2 convergence sublayer	227
A.1.1	MA-UNITDATA.request	227
A.1.1.1	Semantics of the service primitive.....	227
A.1.1.2	Appropriate usage	228
A.1.1.3	Effect on receipt.....	228
A.1.2	MA-UNITDATA.indication	228
A.1.2.1	Semantics of the service primitive.....	228

A.1.2.2	When generated	228
A.1.2.3	Appropriate usage	228
A.1.3	MA-UNITDATA-STATUS.indication.....	229
A.1.3.1	Semantics of the service primitive.....	229
A.1.3.2	When generated	229
A.1.3.3	Appropriate usage	229
Annex B (normative) CCM* mode of operation		231
B.1	Introduction.....	231
B.2	Notation and representation	231
B.2.1	Strings and string operations.....	231
B.2.2	Integers, octets, and their representation	231
B.3	Symmetric-key cryptographic building blocks.....	231
B.3.1	Block cipher	231
B.3.2	Mode of operation.....	232
B.4	Specification of generic CCM* mode of operation	232
B.4.1	CCM* mode encryption and authentication transformation.....	232
B.4.1.1	Input transformation	233
B.4.1.2	Authentication transformation	233
B.4.1.3	Encryption transformation	234
B.4.2	CCM* mode decryption and authentication checking transformation	234
B.4.2.1	Decryption transformation	235
B.4.2.2	Authentication checking transformation.....	235
B.4.3	Restrictions	235
Annex C (informative) Test vectors for cryptographic building blocks.....		237
C.1	AES block cipher	237
C.2	Mode of operation.....	237
C.2.1	MAC beacon frame.....	237
C.2.1.1	Description.....	237
C.2.1.2	CCM* mode encryption and authentication transformation.....	238
C.2.1.3	CCM* mode decryption and authentication checking transformation	240
C.2.2	MAC data frame	241
C.2.2.1	Description.....	241
C.2.2.2	CCM* mode encryption and authentication transformation.....	241
C.2.2.3	CCM* mode decryption and authentication checking transformation	243
C.2.3	MAC command frame	245
C.2.3.1	Description.....	245
C.2.3.2	CCM* mode encryption and authentication transformation.....	245
C.2.3.3	CCM* mode decryption and authentication checking transformation	247
Annex D (normative) Protocol implementation conformance statement (PICS) proforma		251
D.1	Introduction.....	251
D.1.1	Scope.....	251
D.1.2	Purpose.....	251
D.2	Abbreviations and special symbols.....	251
D.3	Instructions for completing the PICS proforma.....	252
D.4	Identification of the implementation.....	252
D.5	Identification of the protocol	253
D.6	Global statement of conformance	253
D.7	PICS proforma tables.....	254

D.7.1	Major roles for devices compliant with IEEE Std 802.15.4-2006.....	254
D.7.2	Major capabilities for the PHY	255
D.7.2.1	PHY functions.....	255
D.7.2.2	PHY packet	255
D.7.2.3	Radio frequency (RF)	256
D.7.3	Major capabilities for the MAC sublayer	256
D.7.3.1	MAC sublayer functions.....	256
D.7.3.2	MAC frames	258
Annex E (informative) Coexistence with other IEEE standards and proposed standards.....		261
E.1	Introduction.....	261
E.2	Standards and proposed standards characterized for coexistence.....	261
E.3	General coexistence issues.....	261
E.3.1	Clear channel assessment (CCA).....	262
E.3.2	Modulation.....	262
E.3.2.1	2400 MHz band PHY	262
E.3.2.2	800/900 MHz band PHYs.....	262
E.3.3	ED and LQI.....	263
E.3.4	Low duty cycle.....	263
E.3.5	Low transmit power	263
E.3.5.1	2400 MHz band PHY	263
E.3.5.2	800 MHz band PHYs.....	263
E.3.5.3	900 MHz band PHYs.....	264
E.3.6	Channel alignment	264
E.3.7	Dynamic channel selection	264
E.3.8	Neighbor piconet capability.....	264
E.4	2400 MHz band coexistence performance.....	265
E.4.1	Assumptions for coexistence quantification	265
E.4.1.1	Channel model	265
E.4.1.2	Receiver sensitivity.....	266
E.4.1.3	Transmit power	266
E.4.1.4	Receiver bandwidth	266
E.4.1.5	Transmit spectral masks.....	266
E.4.1.6	IEEE 802.11b transmit PSD	267
E.4.1.7	Interference characteristics	267
E.4.1.8	Bit error rate (BER) calculations	267
E.4.1.9	Packet error rate (PER).....	268
E.4.2	BER model.....	268
E.4.3	Coexistence simulation results.....	268
E.5	800/900 MHz bands coexistence performance	273
E.5.1	Victims and assailants.....	273
E.5.2	Bandwidth.....	273
E.5.3	Path loss model	273
E.5.4	Temporal model.....	274
E.5.5	Coexistence assurance results	275
E.5.5.1	868 MHz BPSK PHY	275
E.5.5.2	868 MHz O-QPSK PHY.....	276
E.5.5.3	868 MHz PSSS PHY	278
E.5.5.4	915 MHz BPSK PHY	279
E.5.5.5	915 MHz O-QPSK PHY	280
E.5.5.6	915 MHz PSSS PHY	281
E.6	Notes on the calculations	282

Annex F (informative) IEEE 802.15.4 regulatory requirements	283
F.1 Introduction.....	283
F.2 Applicable U.S. (FCC) rules.....	285
F.2.1 Section 15.35 of FCC CFR47	285
F.2.2 Section 15.209 of FCC CFR47	287
F.2.3 Section 15.205 of FCC CFR47	287
F.2.4 Section 15.247 of FCC CFR47	288
F.2.5 Section 15.249 of FCC CFR47	289
F.3 Applicable European rules.....	290
F.3.1 European 2400 MHz band rules	291
F.3.2 European 868–870 MHz band rules	292
F.4 Applicable Japanese rules.....	294
F.5 Emissions specification analysis with respect to known worldwide regulations	295
F.5.1 General analysis and impact of detector bandwidth and averaging rules.....	295
F.5.2 Frequency spreading and averaging effects specific to IEEE Std 802.15.4	297
F.6 Summary of out-of-band spurious emissions limits	299
F.7 Phase noise requirements inferred from regulatory limits.....	300
F.8 Summary of transmission power levels.....	301
Annex G (informative) Bibliography	303
G.1 General.....	303
G.2 Regulatory documents	304
Annex H (informative) IEEE list of participants	306