# ISO/IEC/IEEE 8802-1AX:2021-09 (E)

## Telecommunications and exchange between information technology systems - Requirements for local and metropolitan area networks - Part 1AX: Link aggregation

## Contents


Page

1. Overview ... 18

1.1 Scope ... 18
1.2 Purpose ... 18
1.3 State diagram conventions ... 19

2. Normative references ... 20

3. Definitions ... 21

4. Acronyms and abbreviations ... 24

5. Conformance ... 25

5.1 Requirements terminology ... 25
5.2 Protocol implementation conformance statement ... 25
5.3 Link Aggregation ... 25
5.3.2 Link Aggregation options ... 26
5.4 Distributed Resilient Network Interconnect (DRNI) ... 26
5.4.2 DRNI options ... 27

6. Link Aggregation ... 28

6.1 Overview ... 28
6.1.1 Goals and objectives ... 28
6.1.2 Positioning of Link Aggregation within the IEEE 802 architecture ... 29
6.1.3 Protocol Parser/Multiplexer ... 29
6.1.3.1 Protocol Parser state diagram ... 30
6.2 Link Aggregation operation ... 31
6.2.1 Principles of Link Aggregation ... 33
6.2.2 Service interfaces ... 34
6.2.3 Frame Collector ... 34
6.2.3.1 Frame Collector state diagram ... 35
6.2.4 Frame Distributor ... 36
6.2.4.1 Frame Distributor state diagram ... 36
6.2.5 Marker Generator/Receiver (optional) ... 37
6.2.6 Marker Responder ... 38
6.2.7 Aggregator Parser/Multiplexer ... 38
6.2.7.1 Aggregator Parser/Multiplexer state diagrams ... 38
6.2.8 Aggregator ... 42
6.2.9 LACP Parser/Multiplexer ... 43
6.2.10 Addressing ... 43
6.2.10.1 Source address (SA) ... 43
6.2.10.2 Destination address (DA) ... 43
6.3 Link Aggregation Control ... 44
6.3.1 Characteristics of Link Aggregation Control ... 45
6.3.2 System identification ... 46
6.3.3 Aggregator identification ... 46
6.3.4 Port identification ... 46
6.3.5 Capability identification ... 47
6.3.6 Link Aggregation Group identification ... 48

6.3.6.1 Construction of the Link Aggregation Group Identifier ..... 48
6.3.6.2 Representation of the Link Aggregation Group Identifier ..... 48
6.3.7 Selecting a Link Aggregation Group ..... 49
6.3.8 Agreeing on a Link Aggregation Group ..... 49
6.3.9 Attaching a link to an Aggregator ..... 50
6.3.10 Signaling readiness to transfer user data ..... 50
6.3.11 Enabling the Frame Collector and Frame Distributor ..... 50
6.3.12 MAC_Operational status ..... 51
6.3.13 Monitoring the membership of a Link Aggregation Group ..... 51
6.3.14 Detaching a link from an Aggregator ..... 51
6.3.15 Configuration and administrative control of Link Aggregation ..... 52
6.3.16 Link Aggregation Control state information ..... 52
6.4 Link Aggregation Control Protocol ..... 52
6.4.1 LACP design elements ..... 52
6.4.2 LACPDU structure and encoding ..... 53
6.4.2.1 Transmission and representation of octets ..... 53
6.4.2.2 Encapsulation of LACPDUs in frames ..... 53
6.4.2.3 LACPDU structure ..... 54
6.4.2.4 Version 2 TLVs ..... 57
6.4.3 LACP state machine overview ..... 59
6.4.4 Constants ..... 60
6.4.5 Variables associated with each Aggregator ..... 61
6.4.6 Variables associated with each Aggregation Port ..... 63
6.4.7 Variables used for managing the operation of the state machines ..... 68
6.4.8 Functions ..... 69
6.4.9 Timers ..... 72
6.4.10 Messages ..... 72
6.4.11 LACP Receive machine ..... 72
6.4.12 Selection Logic ..... 74
6.4.12.1 Selection Logic—Requirements ..... 75
6.4.12.2 Selection Logic—Recommended default operation ..... 77
6.4.13 Mux machine ..... 78
6.4.14 LACP Transmit machine ..... 81
6.5 Marker protocol ..... 82
6.5.1 Introduction ..... 82
6.5.2 Sequence of operations ..... 83
6.5.3 Marker and Marker Response PDU structure and encoding ..... 83
6.5.3.1 Transmission and representation of octets ..... 83
6.5.3.2 Encapsulation of Marker and Marker Response PDU in frames ..... 83
6.5.3.3 Marker and Marker Response PDU structure ..... 84
6.5.4 Protocol definition ..... 85
6.5.4.1 Operation of the marker protocol ..... 85
6.5.4.2 Marker Responder state diagram ..... 86
6.6 Conversation-Sensitive Collection and Distribution ..... 87
6.6.1 Port Algorithms and Port Conversation IDs ..... 89
6.6.2 Link numbers and link selection ..... 89
6.6.3 Conversation-sensitive LACP ..... 90
6.6.3.1 Per-Aggregator variables ..... 91
6.6.3.2 Variables associated with each Aggregation Port ..... 94
6.6.3.3 Variables used for managing the operation of the state diagrams ..... 95
6.6.3.4 Functions ..... 96
6.6.3.5 Update Mask machine ..... 100
6.7 Configuration capabilities and restrictions ..... 102
6.7.1 Use of system and port priorities ..... 102

6.7.2 Dynamic allocation of operational Keys ..... 103
6.7.3 Link Aggregation on shared-medium links ..... 103
6.7.4 Selection Logic variants ..... 104
6.7.4.1 Reduced reconfiguration ..... 104
6.7.4.2 Limited Aggregator availability ..... 104
6.7.5 LACP configuration for dual-homed Systems ..... 104

7. Management ..... 106

7.1 Overview ..... 106
7.1.1 Systems management overview ..... 106
7.1.2 Management model ..... 107
7.2 Managed objects ..... 107
7.2.1 Introduction ..... 107
7.2.2 Overview of managed objects ..... 108
7.2.2.1 Text description of managed objects ..... 108
7.2.3 Containment ..... 108
7.2.4 Naming ..... 109
7.2.5 Capabilities ..... 109
7.3 Management for Link Aggregation ..... 114
7.3.1 Aggregator managed object class ..... 114
7.3.1.1 Aggregator attributes ..... 115
7.3.1.2 Aggregator Notifications ..... 125
7.3.2 Aggregation Port managed object class ..... 125
7.3.2.1 Aggregation Port Attributes ..... 125
7.3.2.2 Aggregation Port Extension Attributes ..... 132
7.3.3 Aggregation Port Statistics managed object class ..... 133
7.3.3.1 Aggregation Port Statistics attributes ..... 133
7.3.4 Aggregation Port Debug Information managed object class ..... 134
7.3.4.1 Aggregation Port Debug Information attributes ..... 135
7.4 Management for Distributed Resilient Network Interconnect ..... 137
7.4.1 DRNI Managed Object Class ..... 137
7.4.1.1 DRNI Attributes ..... 137

8. Distribution algorithms ..... 148

8.1 Distribution algorithm identification ..... 148
8.2 Per-Service Frame Distribution ..... 149
8.2.1 Distribution based on C-VLAN Identifier (C-VID) ..... 149
8.2.2 Distribution based on S-VLAN Identifier (S-VID) ..... 150
8.2.3 Distribution based on Backbone Service Instance Identifier (I-SID) ..... 150
8.2.4 Distribution based on Traffic Engineering Service Instance Identifier (TE-SID) 150
8.2.5 Distribution based on Flow Hash ..... 150

9. Distributed Resilient Network Interconnect ..... 151

9.1 Goals ..... 151
9.2 Distributed Relay operation ..... 152
9.3 Intra-Relay Connection ..... 154
9.4 Using DRNI ..... 155
9.4.1 DRNI connectivity ..... 155
9.4.2 DRNI fault recovery ..... 157
9.4.3 DRNI configuration ..... 158

9.5 DRNI Gateway ..... 159
9.5.1 DRCP Parser/Multiplexer ..... 160
9.5.2 DRNI Gateway Relay ..... 160
9.5.2.1 Service interfaces ..... 160
9.5.2.2 variables ..... 161
9.5.2.3 Functions ..... 162
9.5.2.4 Messages ..... 162
9.5.2.5 DR_Gateway Collector/Distributor ..... 162
9.5.2.6 DR_Aggregator Parser/Multiplexer ..... 163
9.5.2.7 DR_IRP Parser/Multiplexer ..... 164
9.5.3 DRNI Gateway Control ..... 165
9.5.3.1 DRNI Gateway and DRNI Identification ..... 165
9.5.3.2 Forming the DRNI ..... 166
9.5.3.3 Partner Selection and Forming a LAG ..... 166
9.5.3.4 Port Algorithm and Aggregator Port Selection ..... 166
9.5.3.5 Gateway Algorithm and DRNI Gateway Port selection ..... 167
9.6 Distributed Relay Control Protocol ..... 168
9.6.1 DRCPDU transmission, addressing, and protocol identification ..... 169
9.6.1.1 Destination MAC Address ..... 169
9.6.1.2 Source MAC Address ..... 170
9.6.1.3 Priority ..... 170
9.6.1.4 Protocol Identification ..... 170
9.6.1.5 Encapsulation of DRCPDUs in frames ..... 170
9.6.2 DRCPDU structure and encoding ..... 170
9.6.2.1 Transmission and representation of octets ..... 170
9.6.2.2 DRCP TLV structure ..... 171
9.6.2.3 DRCPDU structure ..... 172
9.6.2.4 Aggregator State TLV ..... 174
9.6.2.5 Gateway State TLV ..... 176
9.6.2.6 Gateway Preference TLV ..... 176
9.6.2.7 Organization-Specific TLV ..... 177
9.6.3 DRCP state machine overview ..... 178
9.6.4 Constants ..... 179
9.6.5 Variables associated with the DRNI Gateway ..... 179
9.6.6 Variables used for managing the operation of the state machines ..... 185
9.6.7 Functions ..... 187
9.6.8 Timers ..... 194
9.6.9 Messages ..... 194
9.6.10 DRCP Receive machine ..... 195
9.6.11 Distributed Relay machine ..... 197
9.6.12 DRNI Gateway and Aggregator machine ..... 198
9.6.13 DRCP Transmit machine ..... 199

Annex A (normative) Protocol implementation conformance statement (PICS) proforma ..... 200
A.1 Introduction ..... 200
A.1.1 Abbreviations and special symbols ..... 200
A.1.2 Instructions for completing the PICS proforma ..... 201
A.1.3 Additional information ..... 201
A.1.4 Exceptional information ..... 201
A.1.5 Conditional items ..... 202
A.1.6 Identification ..... 202
A.1.6.1 Implementation identification ..... 202
A.1.6.2 Protocol summary ..... 202

A.2 PICS proforma for Clause 6 ... 203
A.2.1 Major capabilities/options ... 203
A.2.3 Protocol Parser/Multiplexer support ... 204
A.2.4 Frame Collector ... 204
A.2.5 Frame Distributor ... 204
A.2.2 LLDP Port connectivity ... 204
A.2.7 Aggregator Parser/Multiplexer ... 205
A.2.8 LACP Parser/Multiplexer ... 205
A.2.6 Marker protocol ... 205
A.2.10 Aggregator identification ... 206
A.2.11 Port identification ... 206
A.2.12 Capability identification ... 206
A.2.9 System identification ... 206
A.2.14 Detaching a link from an Aggregator ... 207
A.2.15 LACPDU structure ... 207
A.2.16 Receive machine ... 207
A.2.13 Link Aggregation Group identification ... 207
A.2.18 Mux machine ... 208
A.2.17 Selection Logic ... 208
A.2.20 Marker protocol ... 209
A.2.19 Transmit machine ... 209
A.2.21 Management ... 210
A.2.23 Conversation-sensitive frame collection and distribution ... 211
A.2.22 Per-Service Frame Distribution ... 211
A.2.25 Link Aggregation on shared-medium links ... 212
A.2.24 Configuration capabilities and restrictions ... 212
A.2.27 DRCPDU structure ... 213
A.2.26 Distributed Resilient Network Interconnect ... 213

Annex B (informative) Collection and distribution algorithms ... 214
B.1 Introduction ... 214
B.2 Port selection ... 215
B.3 Dynamic reallocation of conversations to different Aggregation Ports ... 215
B.4 Topology considerations in the choice of distribution algorithm ... 216

Annex C (informative) LACP standby link selection and dynamic Key management ... 218
C.1 Introduction ... 218
C.2 Goals ... 218
C.3 Standby link selection ... 219
C.4 Dynamic Key management ... 219
C.5 A dynamic Key management algorithm ... 219
C.6 Example 1 ... 221
C.7 Example 2 ... 221

Annex D (normative) SMIv2 MIB definitions for Link Aggregation ... 223
D.1 Introduction ... 223
D.2 SNMP Management Framework ... 223
D.3 Security considerations ... 223
D.4 Structure of the MIB module ... 224
D.4.1 Relationship to the managed objects defined in Clause 7 ... 225
D.4.2 MIB Subtrees ... 232
D.4.2.1 The dot3adAgg Subtree ... 232
D.4.2.2 The dot3adAggPort Subtree ... 232

D.4.2.3 The dot3adAggNotifications Subtree ..... 232
D.4.2.4 The dot3adDrni Subtree ..... 232
D.5 Relationship to other MIBs ..... 233
D.5.1 Relationship to the Interfaces MIB ..... 233
D.5.2 Layering model ..... 233
D.5.3 ifStackTable ..... 234
D.5.4 ifRcvAddressTable ..... 234
D.6 Definitions for Link Aggregation MIB ..... 234

Annex E (informative) DRNI on Bridges ..... 325
E.1 DRNI on VLAN Bridges ..... 325
E.2 DRNI on Provider Bridges and Provider Edge Bridges ..... 326
E.3 DRNI on Backbone Edge Bridges ..... 327

Annex F (normative) Link Aggregation and Link Layer Discovery Protocol ..... 328
F.1 Positioning Link Layer Discovery Protocol (LLDP) relative to Link Aggregation ..... 328
F.1.1 LLDP Parser/Multiplexer ..... 328
F.2 Link Aggregation TLV ..... 328
F.2.1 aggregation status ..... 329
F.2.2 aggregated Port ID ..... 329
F.2.3 Link Aggregation TLV usage rules ..... 329
F.2.4 Use of other TLVs on an Aggregator or Aggregation Link ..... 330

Annex G (informative) Bibliography ..... 331

# Figures


Figure 6-1 Architectural positioning of Link Aggregation sublayer ..... 29
Figure 6-2 Protocol Parser state diagram ..... 31
Figure 6-3 Link Aggregation sublayer block diagram ..... 32
Figure 6-4 Frame Collector state diagram ..... 36
Figure 6-5 Frame Distributor state diagram ..... 37
Figure 6-6 Aggregator Parser state diagram ..... 41
Figure 6-7 Aggregator Multiplexer state diagram ..... 42
Figure 6-8 LACPDU structure ..... 54
Figure 6-9 Bit encoding of the Actor_State and Partner_State fields ..... 55
Figure 6-10 Port Algorithm TLV ..... 57
Figure 6-11 Port Conversation Link Digest TLV ..... 58
Figure 6-12 Port Conversation Service Digest TLV ..... 58
Figure 6-13 LACP state machine overview ..... 59
Figure 6-14 LACP Receive state diagram ..... 73
Figure 6-15 Selection of Aggregators ..... 78
Figure 6-16 Mux state diagram ..... 79
Figure 6-17 LACP Transmit state diagram ..... 81
Figure 6-18 Marker protocol time sequence diagram ..... 83
Figure 6-19 Marker PDU and Marker Response PDU structure ..... 84
Figure 6-20 Marker Responder state diagram ..... 86
Figure 6-21 Conversation-Sensitive Collection and Distribution overview ..... 88
Figure 6-22 Distribution algorithm information flow ..... 91
Figure 6-23 Update Mask state diagram ..... 101
Figure 6-24 Dual-homed System examples ..... 105
Figure 7-1 Link aggregation entity relationship diagram ..... 109
Figure 8-1 Distribution algorithm identifiers ..... 148
Figure 9-1 A DRNI ..... 153
Figure 9-2 Transmission and reception via the IRC ..... 154
Figure 9-3 DRNI with dedicated IRC Link ..... 155
Figure 9-4 DRNI with dedicated IRC LAG ..... 155
Figure 9-5 DRNI end station attach ..... 156
Figure 9-6 DRNI network attach ..... 156
Figure 9-7 DRNI Gateway block diagram ..... 159
Figure 9-8 DR_Gateway state machine ..... 163
Figure 9-9 DR_Aggregator state machine ..... 164
Figure 9-10 DR_IRP state machine ..... 165
Figure 9-11 Basic TLV format ..... 171
Figure 9-12 DRCPDU structure ..... 172
Figure 9-13 Bit encoding of the Home_IRP_State and Neighbor_IRP_State fields ..... 173
Figure 9-14 Aggregator State TLV ..... 174
Figure 9-15 Bit encoding of the Aggregator_CSCD_State fields ..... 175
Figure 9-16 Gateway State TLV ..... 176
Figure 9-17 Gateway Preference TLV ..... 176
Figure 9-18 Organization-Specific TLV ..... 177
Figure 9-19 DRCP state machine overview ..... 178
Figure 9-20 DRCP Receive machine state diagram ..... 195
Figure 9-21 Distributed Relay machine state diagram ..... 197
Figure 9-22 DRNI Gateway and Aggregator machine state diagram ..... 198
Figure 9-23 DRCP Transmit state diagram ..... 199
Figure B-1 Link aggregation topology examples ..... 217
Figure C-1 Example 1 ..... 221

Figure C-2 Example 2a ..... 222
Figure C-3 Example 2b ..... 222
Figure E-1 DRNI on VLAN Bridges ..... 325
Figure E-2 DRNI on Provider Edge Bridges ..... 326
Figure E-3 DRNI on Backbone Edge Bridges ..... 327
Figure F-1 Link Aggregation TLV format ..... 328

# Tables


Table 6-1 Link Aggregation protocol destination addresses ..... 44
Table 6-2 Example Partner parameters ..... 49
Table 6-3 Slow Protocols EtherType Assignment ..... 53
Table 6-4 Type field values of Version 2 TLVs ..... 57
Table 7–1 Link Aggregation capabilities ..... 110
Table 8-1 IEEE per-service distribution algorithms ..... 149
Table 9-1 Distributed Relay Control Protocol destination addresses ..... 169
Table 9-2 DRNI EtherType Assignment ..... 170
Table 9-3 DRNI Protocol subtypes ..... 170
Table 9-4 Type field values of DRCP TLVs ..... 171
Table F.1 Link aggregation capability/status ..... 329