

**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

Part 17: Resilient packet ring (RPR) access method and physical layer specifications

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

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Abstract: This standard defines the medium access control characteristics, physical layer interface methods and layer management parameters for the resilient packet ring (RPR) access method for ring topologies. A set of protocols for detecting and initializing the shared ring configuration, recovering from failures, and regulating fair access to the shared medium are also described. Specifications are provided for interface to a number of physical layers, supporting data rates up to 10 Gb/s. System considerations and management information base (MIB) specifications are also provided in this standard.

Keywords: fairness, IEEE 802.17, layer management, metropolitan area network (MAN), medium access control, physical layer, protection switching, resilient packet ring (RPR), ring topology, topology detection

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Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
1.3 RPR features	2
1.4 Document structure	2
2. Normative references	4
3. Terms, definitions, and notation	6
3.1 Conformance levels	6
3.2 Terms and definitions	6
3.3 Service definition method and notation	13
3.3.1 Classification of service primitives	13
3.4 State machines	14
3.4.1 State table notation	14
3.5 Arithmetic and logical operators	16
3.6 Numerical representation	16
3.7 Field notations	16
3.7.1 Use of italics	16
3.7.2 Field conventions	17
3.7.3 Field value conventions	17
3.8 Bit numbering and ordering	18
3.9 Byte-sequential formats	18
3.10 Left-to-right ordering	19
3.11 Representation of MAC addresses	20
3.12 Mapping of numeric data values to fields	20
3.13 Informative notes	21
3.14 Conventions for C code used in state machines	21
3.15 Ringlet orientation conventions	21
4. Abbreviations and acronyms	22
5. Architecture overview	24
5.1 Terminology	24
5.2 Layer model	25
5.3 Ring structure	26
5.4 Station structure	26
5.5 MAC architecture	27
5.5.1 Datapath connectivity	27
5.5.2 Ringlet selection	28
5.5.3 MAC datapath flows	29
5.5.4 Receive rules	30
5.6 MAC service	30
5.6.1 MAC data primitives	30
5.6.2 Service classes	31
5.6.3 MAC flow control primitives	32
5.7 Frame transmissions	32
5.7.1 Unicast transmissions	32
5.7.2 Flooded transmissions	33

5.7.3 Multicast transmissions	34
5.8 Frame formats	34
5.9 Frame transmissions	34
5.9.1 Local-source/local-destination transmissions	34
5.9.2 Local-source multicast transmissions.....	35
5.9.3 Local-source unknown-unicast transmissions.....	36
5.9.4 Remote-source unicast transmissions.....	36
5.9.5 Remote-source multicast transmissions	37
5.10 Spatial reuse	38
5.11 Bandwidth allocation	38
5.11.1 Allocation enforcement	39
5.11.2 Allocation consistency	39
5.12 Fairness	41
5.12.1 Equal-weighted fairness	41
5.12.2 Fairness frame distribution	42
5.12.3 Multi-choke fairness frame distribution	42
5.13 Transit-queuing options	42
5.14 Fault response methods.....	43
5.14.1 Fault response mechanisms	43
5.14.2 Protection hierarchy	44
5.14.3 Wrap then steer.....	45
5.15 Topology discovery	45
5.16 Frame ordering.....	46
5.16.1 Strict and relaxed transmissions.....	46
5.17 Operations, administration, and maintenance (OAM).....	46
5.17.1 Echo operations	46
5.17.2 Flushing previously sourced traffic.....	47
5.17.3 Management information base (MIB).....	47
5.18 Spatially aware sublayer	48
5.19 Protected inter-ring connection.....	48
6. Medium access control (MAC) service and reference model	49
6.1 Overview.....	49
6.2 Terminology and variables	49
6.3 Overview of MAC services	50
6.3.1 Service types	50
6.3.2 Service classes.....	51
6.4 MAC services to the client layer.....	52
6.4.1 MA_DATA.request.....	52
6.4.2 MA_DATA.indication	56
6.4.3 MA_CONTROL.request.....	58
6.4.4 MA_CONTROL.indication.....	59
6.5 MAC compliance test points.....	61
6.5.1 1 Gb/s PacketPHY	62
6.5.2 10 Gb/s PacketPHY	62
6.5.3 SONET/SDH	62
6.6 MAC reference model	62
6.6.1 MAC control sublayer.....	63
6.6.2 MAC datapath sublayer.....	64
6.6.3 Flow of data within the MAC	65
6.6.4 Reconciliation sublayer	67
6.6.5 Medium access control.....	67
6.6.6 Operations, administration, and maintenance (OAM)	68

6.6.7	MAC layer management entity (MLME).....	68
6.7	Protocol Implementation Conformance Statement (PICS) proforma for Clause 6	69
6.7.1	Introduction	69
6.7.2	Identification.....	69
6.7.3	PICS tables for Clause 6.....	70
7.	Medium access control datapath	71
7.1	Datapath overview	71
7.2	Terminology and variables.....	72
7.2.1	Common state machine definitions	72
7.2.2	Common state machine variables.....	74
7.2.3	Common state machine routines	77
7.2.4	Variables and literals defined in other clauses	79
7.2.5	Flow count variables.....	81
7.3	Service classes.....	83
7.3.1	Service class classA.....	84
7.3.2	Service class classB.....	85
7.3.3	Service class classC.....	86
7.3.4	Reclamation.....	86
7.4	Datapaths.....	86
7.4.1	Add paths.....	86
7.4.2	Transit paths	87
7.4.3	Passthrough mode.....	88
7.4.4	Protection datapaths.....	88
7.5	Rate control	93
7.5.1	MAC shaper overview.....	93
7.5.2	Add queue flow control	94
7.5.3	IdleShaper state machine.....	95
7.5.4	MacControlShaper state machine.....	97
7.5.5	ClassAShaper state machine.....	98
7.5.6	ClassBShaper state machine.....	101
7.5.7	Fairness eligible shaper state machines	104
7.5.8	DownstreamShaper state machine.....	110
7.6	Receive operation.....	112
7.6.1	Receive operation for strict data frames	112
7.6.2	Reception in wrapping systems	114
7.6.3	Receive operation state machines.....	115
7.6.4	WrongRinglet state machine	145
7.7	Transmit operation	146
7.7.1	Ringlet selection	147
7.7.2	Determination of cleave point	159
7.7.3	Setting of <i>ttl</i> and <i>ttlBase</i>	160
7.7.4	StageQueueSelection state machine	163
7.7.5	DataAddCount state machine	168
7.7.6	ControlAddCount state machine	170
7.7.7	Single queue MAC design.....	172
7.7.8	Dual queue MAC design	175
7.7.9	TransmitCount state machine	179
7.7.10	TransmitRoute state machine	182
7.8	Protocol Implementation Conformance Statement (PICS) proforma for Clause 7	184
7.8.1	Introduction	184
7.8.2	Identification.....	184
7.8.3	PICS tables for Clause 7.....	185

8. MAC physical interface	189
8.1 Overview.....	189
8.1.1 Objectives.....	189
8.1.2 Relationship to other standards	190
8.2 MAC physical layer service interface.....	190
8.2.1 PHY_DATA.request	190
8.2.2 PHY_DATA.indication.....	191
8.2.3 PHY_LINK_STATUS.indication	192
8.2.4 Mapping of PHY_READY.indication	193
8.3 PacketPHY physical layer interfaces and PHYs.....	193
8.3.1 PacketPHY reconciliation sublayers	193
8.3.2 PacketPHYs.....	194
8.4 SONET/SDH physical layer interfaces and PHYs	195
8.4.1 SONET/SDH reconciliation sublayers.....	196
8.4.2 SONET/SDH adaptation sublayers	196
8.4.3 SONET/SDH physical layer entities (PHYs).....	198
8.5 Protocol Implementation Conformance Statement (PICS) proforma for Clause 8	200
8.5.1 Introduction	200
8.5.2 Identification	200
8.5.3 Major capabilities/options	201
8.5.4 PICS tables for Clause 8.....	201
9. Frame formats	203
9.1 Overview.....	203
9.2 Data frame format.....	203
9.2.1 Data frame sizes	203
9.2.2 Data frame fields	204
9.3 Control frame format	205
9.3.1 Control frame sizes.....	205
9.3.2 Control frame fields	206
9.4 Fairness frame format	208
9.4.1 Fairness frame sizes	208
9.4.2 Fairness frame fields	208
9.5 Idle frame format	209
9.5.1 Idle frame sizes.....	209
9.5.2 Idle frame fields	209
9.6 <i>baseControl</i> subfields	210
9.7 <i>extendedControl</i> subfields	212
9.8 Protocol Implementation Conformance Statement (PICS) proforma for Clause 9	214
9.8.1 Introduction	214
9.8.2 Identification	214
9.8.3 PICS tables for Clause 9.....	215
10. Fairness	216
10.1 Overview.....	216
10.1.1 Fairness instances.....	216
10.1.2 Services and features.....	219
10.1.3 Fairness algorithm overview	219
10.2 Terms, definitions, variables, and routines	230
10.2.1 Common state machine definitions	230
10.2.2 Common state machine variables.....	231

10.2.3	Common state machine routines	235
10.2.4	Variables and routines defined in other clauses	236
10.3	Frame formats	237
10.3.1	Fairness frame format	237
10.3.2	Fairness differential delay (FDD) frame format	238
10.4	Fairness state machines	238
10.4.1	PerByte state machine	239
10.4.2	PerAgingInterval state machine	242
10.4.3	AggressiveRateAdjust state machine	246
10.4.4	ConservativeRateAdjust state machine	248
10.4.5	PerAdvertisingInterval state machine	251
10.4.6	PerReportingInterval state machine	255
10.4.7	ActiveWeightsComputation state machine	256
10.4.8	FairnessFrameReceive state machine	258
10.4.9	FddFrameTransmit state machine	261
10.4.10	FrttComputation state machine	262
10.5	Explanation of aging and rates (informative)	268
10.6	Protocol Implementation Conformance Statement (PICS) proforma for Clause 10	271
10.6.1	Introduction	271
10.6.2	Identification	271
10.6.3	PICS tables for Clause 10	272
11.	Topology discovery and protection	274
11.1	Overview	274
11.1.1	Protocol overview	275
11.1.2	Topology database maintenance	276
11.1.3	Context containment	277
11.1.4	Secondary MAC addresses	278
11.1.5	LRTT measurement protocol	278
11.1.6	Fault response mechanisms	279
11.2	Terminology and variables	280
11.2.1	Terminology	280
11.2.2	Common state machine definitions	281
11.2.3	Common state machine variables	282
11.2.4	<i>ringInfo</i> fields	284
11.2.5	<i>myTopoInfo</i> fields	285
11.2.6	<i>topoEntry[rid][hops]</i> fields	287
11.2.7	Common state machine routines	288
11.2.8	Variables and routines defined in other clauses	290
11.2.9	Defect indications	290
11.3	Frame formats	292
11.3.1	Topology and protection (TP) frame format	292
11.3.2	Topology checksum (TC) frame format	293
11.3.3	Loop round-trip time request frame format	295
11.3.4	Loop round-trip time response frame format	296
11.3.5	ATD frame format	296
11.4	Defined ATT encodings	298
11.4.1	Weight ATT	298
11.4.2	Station bandwidth ATT	299
11.4.3	Station settings ATT	299
11.4.4	Station name ATT	300
11.4.5	Management address ATT	300
11.4.6	Station interface index ATT	301

11.4.7	Secondary MAC ATT	301
11.4.8	Organization-specific ATT	302
11.5	Topology database	303
11.5.1	Topology database structure.....	303
11.5.2	Attribute updates	307
11.5.3	Lower level representation of topology database.....	307
11.5.4	Topology change sequence	308
11.6	State machines	310
11.6.1	State machine functions	310
11.6.2	ReceiveMonitor state machine	311
11.6.3	TopologyControl state machine	313
11.6.4	ParseTpFrame state machine.....	317
11.6.5	ProtectionUpdate state machine	321
11.6.6	TopologyValidation state machine.....	330
11.6.7	TransmitTpFrame state machine.....	336
11.6.8	ReceiveTpFrame state machines.....	338
11.6.9	TransmitTcFrame state machine	340
11.6.10	ReceiveTcFrame state machine.....	342
11.6.11	Transmit rules for ATD frames	343
11.6.12	Receive rules for ATD frames	344
11.6.13	SecondaryUpdate state machine.....	345
11.6.14	TimingLrttFrame state machine	350
11.7	Protocol Implementation Conformance Statement (PICS) proforma for Clause 11	355
11.7.1	Introduction	355
11.7.2	Identification	355
11.7.3	PICS tables for Clause 11.....	356
12.	Operations, administration, and maintenance (OAM)	360
12.1	Overview.....	360
12.1.1	Protocol overview	360
12.1.2	OAM functions supported by RPR	361
12.1.3	Fault management	361
12.1.4	Echo operations	362
12.1.5	Flush operations	362
12.1.6	Organization-specific operations.....	363
12.1.7	SAS notify operations	363
12.1.8	PIRC management operations	363
12.2	Terminology and variables	363
12.2.1	Common state machine definitions	363
12.2.2	Common variables.....	363
12.2.3	Common routines	364
12.2.4	Literals and routines defined in other clauses	364
12.3	OAM frame formats.....	365
12.3.1	Echo request/response payload	365
12.3.2	Flush frame.....	366
12.3.3	Organization-specific frame.....	367
12.3.4	SAS notify frame.....	368
12.3.5	PIRC frame.....	369
12.4	OAM service primitives.....	371
12.4.1	Echo MA_CONTROL.request.....	371
12.4.2	Echo MA_CONTROL.indication	372
12.4.3	Flush MA_CONTROL.request	372
12.4.4	Flush MA_CONTROL.indication.....	373

12.4.5	Organization-specific MA_CONTROL.request.....	373
12.4.6	Organization-specific MA_CONTROL.indication	374
12.4.7	SAS notify MA_CONTROL.request	375
12.5	OAM state machines	376
12.5.1	OamFrameTransmit state machine	376
12.5.2	OamFrameReceive state machine	377
12.6	Performance monitoring	380
12.6.1	Performance monitoring counters	380
12.6.2	Available and unavailable seconds	381
12.7	Protocol Implementation Conformance Statement (PICS) proforma for Clause 12	382
12.7.1	Introduction	382
12.7.2	Identification.....	382
12.7.3	PICS tables for Clause 12.....	383
13.	Layer management entity interface	386
13.1	Overview of the management model	386
13.2	MLME service interface	386
13.2.1	MLME_GET.request.....	387
13.2.2	MLME_SET.request	387
13.2.3	MLME_EVENT.indication	388
13.2.4	MLME_RESET.request	389
13.3	MLME services.....	390
13.3.1	RPR interface configuration	390
13.3.2	Topology discovery monitoring	391
13.3.3	Performance and accounting measurements	391
13.4	Protocol Implementation Conformance Statement (PICS) proforma for Clause 13	394
13.4.1	Introduction	394
13.4.2	Identification.....	394
13.4.3	PICS tables for Clause 13.....	395
14.	Spatially aware sublayer.....	396
14.1	Spatially aware sublayer overview	396
14.2	Terminology and variables.....	397
14.2.1	Common definitions	397
14.2.2	Common state machine variables.....	397
14.2.3	Common state machine routines	398
14.2.4	Variables and literals defined in other clauses	398
14.2.5	SAS database fields	399
14.2.6	SAS statistics counters	401
14.3	SAS association database.....	401
14.3.1	Logical representation of SAS tables	401
14.3.2	Static unicast entries	403
14.3.3	Static multicast entries.....	403
14.3.4	Dynamic entries.....	403
14.3.5	Mapping of VIDs to FIDs.....	404
14.4	SDB operations	404
14.4.1	SAS learning process.....	404
14.4.2	Querying the SDB	405
14.4.3	SDB entry removal	405
14.5	SAS operations.....	406
14.5.1	Principles of unicast operation	406
14.5.2	Principles of multicast operation	407

14.5.3	Transmit operation	409
14.5.4	SAS receive operation	412
14.6	Protocol Implementation Conformance Statement (PICS) proforma for Clause 14	415
14.6.1	Introduction	415
14.6.2	Identification	415
14.6.3	PICS tables for Clause 14.....	416
15.	Protected inter-ring connection.....	418
15.1	Protected inter-ring connection overview.....	418
15.1.1	PIRC stations.....	418
15.1.2	PIRC load balancing.....	419
15.1.3	PIRC misconfiguration detection	419
15.1.4	PIRC failure conditions	419
15.1.5	PIRC maintenance commands	419
15.1.6	PIRC reversion mode	420
15.1.7	PIRC protection hierarchy.....	420
15.1.8	PIRC ring-interconnection forwarding states.....	420
15.2	Terminology and variables	420
15.2.1	Common state machine definitions	420
15.2.2	Common state machine variables.....	421
15.2.3	Common state machine routines	421
15.2.4	Variables and literals defined in other clauses	422
15.3	PIRC database.....	423
15.3.1	pircProv provisioning database	423
15.3.2	pircInfo dynamic information database.....	424
15.3.3	pircMateMsg mate information database	424
15.4	State machines	424
15.4.1	PircMateMsgReceive state machine	424
15.4.2	PircControl state machine	425
15.4.3	PircProtectionUpdate state machine.....	427
15.4.4	PircMateMsgTransmit state machine.....	431
15.5	PIRC operations.....	432
15.5.1	PIRC receive operation	432
15.5.2	PIRC transmit operation.....	434
15.6	Protocol Implementation Conformance Statement (PICS) proforma for Clause 15	436
15.6.1	Introduction	436
15.6.2	Identification	436
15.6.3	PICS tables for Clause 15.....	437
Annex A	(informative) Bibliography	438
Annex B	(normative) PacketPHY reconciliation sublayers.....	440
B.1	Overview.....	440
B.2	1 Gb/s PacketPHY reconciliation sublayer (PRS-1).....	440
B.2.1	General requirements	441
B.2.2	GMII data stream	445
B.2.3	GMII functional specifications.....	445
B.2.4	Electrical characteristics.....	446
B.3	10 Gb/s PacketPHY Reconciliation Sublayer (PRS-10).....	446
B.3.1	General requirements	446
B.3.2	XGMII data stream.....	451
B.3.3	Functional specifications.....	451

B.3.4	Electrical characteristics	452
B.3.5	XGXS and XAUI	452
B.4	Protocol Implementation Conformance Statement (PICS) proforma for Annex B	453
B.4.1	Introduction	453
B.4.2	Identification.....	453
B.4.3	Major capabilities/options	454
B.4.4	PICS tables for Annex B	454
Annex C	(normative) SONET/SDH reconciliation sublayers.....	456
C.1	Overview	456
C.1.1	Relationship to other sublayers	456
C.1.2	SRS and GRS interfaces.....	456
C.1.3	Link status signals	458
C.1.4	Electrical specifications.....	459
C.2	Physical frame format for SRS and GRS.....	459
C.2.1	SRS physical frame format.....	459
C.2.2	GRS physical frame format.....	460
C.3	SRS and GRS using the 8-bit SPI-3 interface.....	462
C.3.1	General requirements.....	462
C.3.2	Mapping of SPI-3 signals to service interface primitives	465
C.3.3	SRS and GRS 8-bit SPI datastream.....	467
C.3.4	Functional specifications	467
C.3.5	Electrical specifications.....	467
C.4	SRS and GRS using the 32-bit SPI-3 interface.....	467
C.4.1	General requirements.....	467
C.4.2	Mapping of SPI-3 signals to service interface primitives	471
C.4.3	SRS and GRS 32-bit SPI datastream.....	475
C.4.4	Functional specifications	475
C.4.5	Electrical timing specifications	475
C.5	SRS and GRS using the SPI-4 Phase 1 interface	475
C.5.1	General requirements.....	475
C.5.2	Mapping of SPI-4 signals to service interface primitives	479
C.5.3	SRS and GRS 64-bit SPI datastream.....	481
C.5.4	Functional specifications	481
C.5.5	Electrical specifications.....	481
C.6	SRS and GRS using SPI-4.2 interface	481
C.6.1	General requirements.....	482
C.6.2	Mapping of SPI-4 signals to service interface primitives	485
C.6.3	SRS and GRS SPI-4.2 datastream	486
C.6.4	Functional specifications	486
C.6.5	Electrical specifications.....	486
C.7	Protocol Implementation Conformance Statement (PICS) proforma for Annex C	487
C.7.1	Introduction	487
C.7.2	Identification.....	487
C.7.3	Major capabilities/options	488
C.7.4	PICS tables for Annex C	488
Annex D	(normative) SNMP MIB definitions	491
D.1	Introduction.....	491
D.2	The SNMP management framework.....	491
D.3	Security considerations	491
D.4	MIB Structure	493

D.4.1 Structure of the MIB	493
D.5 Relationship to other MIBs	494
D.5.1 Relationship to the Interfaces MIB	494
D.5.2 Relationship to PHY MIBs	497
D.6 Definitions for the RPR MIB	497
Annex E (normative) CRC and parity calculations	643
E.1 Cyclic redundancy check 16-bit (CRC16) algorithmic definition	643
E.1.1 Serial CRC16 calculation	643
E.1.2 CRC16 calculations	644
E.1.3 Protected header-field changes	644
E.1.4 Illustration of CRC16 checks	645
E.2 Cyclic redundancy check 32-bit (CRC32) algorithmic definition	645
E.2.1 Serial CRC32 calculation	646
E.2.2 Exchanged ExorSum calculations	647
E.2.3 Payload CRC stomping	647
E.2.4 Illustration of CRC32 checks	648
E.3 Parity algorithmic definition	649
E.3.1 Parity calculation	649
E.3.2 Illustration of fairness-frame checks	649
E.4 Protocol Implementation Conformance Statement (PICS) proforma for Annex E	650
E.4.1 Introduction	650
E.4.2 Identification	650
E.4.3 PICS tables for Annex E	651
Annex F (informative) 802.1D and 802.1Q bridging conformance	652
F.1 Bridging overview	652
F.1.1 802 bridging reference model	652
F.1.2 RPR support of the MAC service	653
F.1.3 Transmission between local and remote end stations	653
F.1.4 Maintaining filtering integrity of the 802 bridged network	655
F.1.5 RPR support for basic bridging model with spatial reuse for local hosts	659
F.1.6 Duplication/misordering prevention	659
F.1.7 MAC client invocation of optional RPR service parameters	660
F.1.8 RPR requirements for 802.1D and 802.1Q bridging conformance	660
F.2 Architectural model of an 802.1D compliant RPR bridge	661
F.2.1 Bridge relay entity	661
F.2.2 Ports	661
F.2.3 Higher layer entities	661
F.3 RPR MAC Internal Sublayer Service	662
F.3.1 RPR MAC support of Internal Sublayer Service	662
F.3.2 RPR MAC support of Enhanced Internal Sublayer Service	662
F.4 Bridge protocol entity interactions	666
F.5 MAC client transmission requirements	666
F.6 MAC client reception requirements	667
Annex G (informative) Implementation guidelines	669
G.1 Sizing of secondary transit queue and <i>addRateA1</i>	669
G.1.1 Calculation of minimum size for secondary transit queue	669
G.1.2 Calculation of maximum <i>addRateA1</i>	670
G.2 ClassA shaping effects on jitter	670

G.2.1 ClassA shaper characteristics	670
G.2.2 ClassA shaper behaviors.....	671
G.2.3 ClassA clamped-credit shaper behaviors.....	671
Annex H (informative) C-code illustrations of CRC computations	673
Annex I (informative) Datapath scenarios	688
I.1 Duplicate frame scenarios.....	688
I.1.1 Unidirectional source bypass.....	688
I.1.2 Unidirectional wrapped source bypass.....	689
I.1.3 Bidirectional destination bypass.....	689
I.1.4 Bidirectional destination removals.....	690
I.1.5 Source and destination removals	690
I.2 Reordered frame scenarios.....	691
I.2.1 Protection switch during bidirectional flood	691
I.2.2 Cascading failures during bidirectional flood	692
I.2.3 Protection switch during unicast transmission on steering system	693
I.2.4 Cascading protection switch during unidirectional flood, wrapping.....	694
Annex J (informative) Spatial indications and shaping.....	695
J.1 Overview	695
J.2 Spatial bandwidth allocation.....	696
J.2.1 Single queue spatial allocation	696
J.2.2 Dual queue spatial allocation.....	697
J.2.3 Cumulative ringlet allocation	698
J.3 Spatial client queuing.....	699
Annex K (informative) Client-based OAM operations using echo and flush	701
K.1 Connectivity monitoring using echo request/response	701
K.1.1 Background.....	701
K.1.2 Scope of operations	701
K.1.3 Connectivity monitor.....	701
K.1.4 Failure declaration and clearing	702
K.2 Resteering using flush.....	703
K.2.1 Background.....	703
K.2.2 Approach	703
K.2.3 Using echo frames to flush steer protected rings.....	704
Index	705

List of tables

Table 3.1—State table notation example	14
Table 3.2—Called state table notation example	15
Table 3.3—Special symbols and operators	16
Table 3.4—Names of fields and subfields	17
Table 3.5— <i>wrap</i> field values	18
Table 5.1—Service classes and their quality-of-service relationships	31
Table 6.1— <i>service_class</i> values	54
Table 6.2— <i>ringlet_id</i> values	54
Table 6.3— <i>flooding_form</i> values	55
Table 6.4—Source address value combinations	56
Table 6.5— <i>reception_status</i> values	57
Table 6.6—Control request opcodes	59
Table 6.7—Control indication opcodes	60
Table 6.8—Compliance test point types	61
Table 7.1—Service classes	84
Table 7.2—Service mapping	88
Table 7.3—Center wrap adjustments	91
Table 7.5— <i>myEdgeState</i> setting	92
Table 7.4—Edge wrap adjustments	92
Table 7.6—Send indication summary	94
Table 7.7—IdleShaper state table	97
Table 7.8—MacControlShaper state table	98
Table 7.9—ClassAShaper state table	100
Table 7.10—ClassBShaper state table	103
Table 7.11—PreCongestionShaper state table	106
Table 7.12—PostCongestionShaper state table	108
Table 7.13—SourceShaper state table	109
Table 7.14—FairnessEligibleIndication state table	111
Table 7.15—DownstreamShaper state table	112
Table 7.16—Strip rules	116
Table 7.17—Client filter selection summary	117
Table 7.18—MAC control filter selection summary	118
Table 7.19—ReceiveFromEdge state table	120
Table 7.20—ReceiveCheck state table	124
Table 7.21—ReceiveCount state table	129
Table 7.22—ReceiveStrip state table	131
Table 7.23—ReceiveAdjust state table	135
Table 7.24—ReceiveFilter state table	137
Table 7.25—ReceiveFilterDataCount state table	140
Table 7.26—ReceiveFilterControlCount state table	143
Table 7.27—WrongRinglet state table	146
Table 7.28—Flooding rules	151
Table 7.29—RingletSelection state table	154
Table 7.30—Initial <i>ttl</i> field values	162
Table 7.31—StageQueueSelection state table	166
Table 7.32—DataAddCount state table	169
Table 7.33—ControlAddCount state table	171
Table 7.34—SingleQueueTransmit state table	174
Table 7.35—DualQueueTransmit state table	178
Table 7.36—TransmitCount state table	180
Table 7.37—TransmitRoute state table	183
Table 8.1—C2 signal labels for GFP and HDLC-like framing	195

Table 8.3—Flag and control escape sequences for HDLC-like framing.....	197
Table 8.2—GFP EXI and UPI values for RPR.....	197
Table 8.4—LAPS frame field values for RPR.....	198
Table 8.5—SONET/SDH supported path layers and capacities.....	199
Table 9.1—Data frame size constraints.....	203
Table 9.2—Control frame size constraints.....	205
Table 9.4— <i>controlType</i> values.....	207
Table 9.3—Control frame constraints for <i>extendedControl</i> subfield values.....	207
Table 9.5—Fairness frame constraints for <i>baseControl</i> subfield values.....	208
Table 9.7— <i>ri</i> values.....	210
Table 9.6—Idle frame constraints for <i>baseControl</i> subfield values.....	210
Table 9.9— <i>sc</i> values.....	211
Table 9.10—Service class and fairness eligible encodings.....	211
Table 9.8— <i>fi</i> values.....	211
Table 9.11—Service class and fairness eligible interpretations.....	212
Table 9.12— <i>fi</i> values.....	213
Table 10.1—Fairness operations.....	230
Table 10.2—The <i>agingInterval</i> as a function of <i>lineRate</i>	232
Table 10.3—Fairness frame type (<i>ffType</i>) values.....	237
Table 10.4—Fairness differential delay frame <i>baseRingControl</i> subfield values.....	238
Table 10.5—PerByte.....	241
Table 10.6—PerAgingInterval.....	246
Table 10.8—AggressiveRateAdjust.....	247
Table 10.9—ConservativeRateAdjust.....	249
Table 10.10—PerAdvertisingInterval.....	253
Table 10.11—PerReportingInterval.....	256
Table 10.12—ActiveWeightsComputation.....	258
Table 10.13—FairnessFrameReceive state table.....	259
Table 10.14—FddFrameTransmit.....	262
Table 10.15—FrttComputation.....	266
Table 10.16—PHY types and associated rates.....	270
Table 11.1—TP frame header field-value restrictions.....	292
Table 11.2— <i>psw</i> and <i>pse</i> values.....	293
Table 11.3—TC frame header field-value restrictions.....	294
Table 11.4—LRTT request frame header field-value restrictions.....	295
Table 11.5—LRTT response frame header field-value restrictions.....	296
Table 11.6—ATD frame header field-value restrictions.....	297
Table 11.7— <i>type</i> encoding for ATD frame.....	297
Table 11.8—Mapping of address type values to supported address types.....	301
Table 11.9—Ring-level topology database: <i>ringInfo</i>	304
Table 11.10—Topology database for local station: <i>myTopoInfo</i>	305
Table 11.11—Topology database for one ringlet: <i>topoEntry</i> [<i>ringlet</i>][<i>hops</i>].....	306
Table 11.12—ReceiveMonitor state table.....	312
Table 11.13—TopologyControl state table.....	315
Table 11.14—ParseTpFrame state table.....	319
Table 11.15—ProtectionUpdate state table.....	326
Table 11.16—TopologyValidation state table.....	334
Table 11.17—TransmitTpFrame state table.....	337
Table 11.18—ReceiveTpFrame state table.....	339
Table 11.19—TransmitTcFrame state table.....	341
Table 11.20—ReceiveTcFrame state table.....	343
Table 11.21—SecondaryUpdate state table.....	349
Table 11.22—TimingLrttFrame state table.....	353
Table 12.1— <i>sesThreshold</i> example values.....	364

Table 12.2— <i>responseRinglet</i> values	366
Table 12.3—SAS notify frame header field-value restrictions	368
Table 12.4—type values	369
Table 12.5—PIRC frame header field-value restrictions	370
Table 12.6—OamFrameTransmit state table	377
Table 12.7—OamFrameReceive state table	379
Table 13.1—Event indications.....	389
Table 13.2—Statistics definitions.....	392
Table 13.3—MAC statistics.....	392
Table 14.2—Example SDB for multicast lookup	402
Table 14.3—Example static unicast management table	402
Table 14.1—Example SDB for unicast lookup	402
Table 14.4—Example static multicast management table	403
Table 14.5—Aging time parameter value.....	404
Table 14.6—purgeScope to purgeValue relationship	405
Table 14.7—Purge invocations.....	406
Table 14.8—SasTransmit state table	411
Table 14.9—SasReceive state table	413
Table 15.1—PIRC pircProv database	423
Table 15.2—PIRC pircInfo database.....	424
Table 15.3—PIRC pircMateMsg database	424
Table 15.4—PircMateMsgReceive state table.....	425
Table 15.5—PircControl state table.....	427
Table 15.6—PircProtectionUpdate state table	429
Table 15.7—PircMateMsgTransmit state table	432
Table 15.8—PircReceive state table	434
Table 15.9—PircTransmit state table	435
Table B.1—Transmit and receive lane associations	449
Table C.1— <i>signalFail</i> and <i>signalDegrade</i> mapping.....	458
Table C.2—GFP payload header field values.....	462
Table C.3— <i>TMOD</i> [1:0] and corresponding valid data	470
Table C.4— <i>RMOD</i> [1:0] and corresponding valid data	471
Table C.6— <i>TxPrty</i> and <i>TxDData</i> parity.....	477
Table C.5— <i>TxSize</i> and corresponding valid data	477
Table C.7— <i>RxPrty</i> and <i>RxDData</i> parity	478
Table C.8— <i>RxSize</i> and corresponding valid data.....	478
Table C.9— <i>TSTAT</i> and corresponding FIFO status	483
Table C.10— <i>RSTAT</i> and corresponding FIFO status	484
Table D.1—RPR MIB SAS read-write and read-create attributes	492
Table D.2—Structure of the MIB	493
Table D.3—Specific interface MIB objects.....	495
Table F.1—Transmit rule requirements.....	667
Table F.2—Combined host/bridge receive rule requirements	668
Table J.1—MAC client interface	699

List of figures

Figure 3.1—Service definitions	13
Figure 3.2—Bit numbering and ordering.....	18
Figure 3.3—Byte-sequential field format illustrations	19
Figure 3.4—Multi-byte field illustrations	19
Figure 3.5—Organization-specific <i>controlDataUnit</i> field format	20
Figure 3.6—48-bit MAC address format	20
Figure 3.8—Ringlet orientation conventions	21
Figure 3.7—Illustration of fairness-frame structure	21
Figure 5.1—RPR service and reference model relationship to the ISO/IEC OSI reference model.....	25
Figure 5.2—Dual-ring structure.....	26
Figure 5.4—Single station view of MAC architecture	27
Figure 5.3—Station structure	27
Figure 5.5—End-to-end view of MAC architecture	28
Figure 5.7—MAC data flows.....	29
Figure 5.6—Secondary address transmissions.....	29
Figure 5.8—MAC service interface	30
Figure 5.9—MAC data primitives	31
Figure 5.10—Unicast frame transmissions.....	32
Figure 5.11—Flooded transmissions	33
Figure 5.12—Cleave point migration	33
Figure 5.13—Basic data frame format.....	34
Figure 5.15—Local-source multicast transmissions.....	35
Figure 5.14—Local-source/local-destination transmissions.....	35
Figure 5.16—Local-source unknown-unicast transmission.....	36
Figure 5.18—Remote-source multicast transmissions.....	37
Figure 5.17—Remote-source unicast transmissions.....	37
Figure 5.19—Bandwidth recycling mechanisms	38
Figure 5.20—ClassA allocation enforcement.....	39
Figure 5.21—Single queue station S1 allocations	40
Figure 5.22—Unregulated vs. equal-weighted fair access on ringlet0	41
Figure 5.23—Fairness frames	42
Figure 5.24—Transit-queuing options	42
Figure 5.25—Fault response mechanisms	44
Figure 5.27—Closed-ring and open-ring topologies	45
Figure 5.26—Protection topologies	45
Figure 5.29—Flushing previously sourced traffic	47
Figure 5.28—Echo operation, ringlet selection possibilities	47
Figure 6.1—RPR service and reference model relationship to the ISO/IEC OSI reference model.....	49
Figure 6.2—MAC service model.....	53
Figure 6.3—MAC test points	61
Figure 6.4—Single station view of MAC architecture	62
Figure 6.5—MAC control architecture	63
Figure 6.6—MAC datapath architecture.....	64
Figure 6.7—MAC reference model, showing internal MAC functions and data paths.....	65
Figure 6.8—MAC reference model continued, showing center wrap data paths	66
Figure 6.9—MAC reference model continued, showing edge wrap data paths	66
Figure 7.1—MAC datapath sublayer relationship to the ISO/IEC OSI reference model	71
Figure 7.2—MAC datapath relationships	72
Figure 7.3—MAC datapaths.....	87
Figure 7.4—Wrap methods.....	89
Figure 7.5—Credit adjustments over time	93
Figure 7.6—Protection event example.....	113

Figure 7.7—Use of <i>ps</i> bit in wrapping systems	115
Figure 7.8—Receive subentities	115
Figure 7.9—Filter subentities	116
Figure 7.10—Rx SAS subentities	118
Figure 7.11—Transmit entities	147
Figure 7.12—Cleave point example	159
Figure 7.13—Odd number of stations cleave point example	160
Figure 7.14—Even number of stations cleave point example	160
Figure 7.15—Single queue MAC datapath.....	173
Figure 7.16—Dual queue MAC datapath	176
Figure 8.1—RPR RS and PHY relationship to the ISO/IEC OSI reference model.....	190
Figure 8.2—RPR in HDLC-like framing structure.....	198
Figure 8.3—RPR in LAPS framing structure	198
Figure 9.1—Data frame formats	204
Figure 9.2—Control frame format	206
Figure 9.3—Fairness frame format.....	208
Figure 9.4—Idle frame format.....	209
Figure 9.5— <i>baseControl</i> field format for data frames	210
Figure 9.6— <i>extendedControl</i> field format for data and control frames	212
Figure 10.1—Fairness function relationship to the ISO/IEC OSI reference model	216
Figure 10.3—Fairness instances on an open ring using steering.....	217
Figure 10.2—Fairness instances on a closed ring.....	217
Figure 10.4—Fairness instances on an open ring using wrapping	218
Figure 10.5—Path of fairness frames on an open ring	218
Figure 10.6—Congestion control objectives	220
Figure 10.7—The <i>fairRate</i> advertised upstream by a single congested station.....	220
Figure 10.8—Path of a rate advertisement	221
Figure 10.9—Congestion control feedback	221
Figure 10.10—Received <i>fairRate</i> more restrictive than local <i>fairRate</i>	222
Figure 10.11—Local <i>fairRate</i> more restrictive than received <i>fairRate</i>	222
Figure 10.12—Advertising the FULL_RATE	223
Figure 10.13—Congestion domains	224
Figure 10.14—Traffic rate measurements	227
Figure 10.15—Fairness frame payload.....	237
Figure 10.16—Fairness differential delay (FDD) payload	238
Figure 10.17—LRTT associated with path that is not wrapped	263
Figure 10.18—Tail downstream of head on same ringlet.....	264
Figure 10.19—Tail upstream of head on opposing ringlet.....	264
Figure 10.20—Tail downstream of head on opposing ringlet	265
Figure 10.21—Rate counter asymptotically approaching rate	269
Figure 11.1—Topology and protection entities relationship to the ISO/IEC OSI reference model.....	274
Figure 11.2—Context containment sequence	278
Figure 11.3—Steering protection of unicast traffic	279
Figure 11.4—Wrapping protection of traffic.....	279
Figure 11.5—Relationship between <i>ri</i> value and east/west.....	280
Figure 11.6—TP payload.....	292
Figure 11.7— <i>protStatus</i> field format.....	292
Figure 11.8— <i>prefs</i> field format	293
Figure 11.10—Alignment of the 32-bit fields used to compute topology checksum	294
Figure 11.9—TC payload	294
Figure 11.12—LRTT request payload.....	295
Figure 11.11— <i>checksumStatus</i> field format.....	295
Figure 11.13—LRTT response payload	296
Figure 11.15—Type-length-value format.....	297

Figure 11.14—Attribute discovery payload.....	297
Figure 11.16—Weight <i>attDataUnit</i> format.....	298
Figure 11.17—Station bandwidth <i>attDataUnit</i> format	299
Figure 11.18—Station settings <i>attDataUnit</i> format.....	299
Figure 11.19—Station name <i>attDataUnit</i> format	300
Figure 11.20—Management address ATT <i>attDataUnit</i> format.....	300
Figure 11.21—Station interface index ATT <i>attDataUnit</i> format	301
Figure 11.23—Organization-specific <i>attDataUnit</i> format.....	302
Figure 11.22—Secondary MAC ATT <i>attDataUnit</i> format.....	302
Figure 11.25—Topology database structure	303
Figure 11.24—Mapping of organization-specific values.....	303
Figure 11.26—Topology database parameters	308
Figure 11.27—Topology change sequences	309
Figure 11.28—Topology and protection relationships	310
Figure 11.29—Protection topologies	322
Figure 11.30—Edge condition updates.....	323
Figure 11.31—Duplicate MAC address scenarios.....	330
Figure 12.1—OAM control entity relationship to the ISO/IEC OSI reference model	360
Figure 12.2—Echo request/response operations.....	362
Figure 12.3—Flushing on an unprotected and wrapped rings	362
Figure 12.4—Echo request/response frame payload format.....	365
Figure 12.5— <i>responseControl</i> field format.....	366
Figure 12.7—Organization-specific frame payload format	367
Figure 12.8—Organization-specific <i>controlDataUnit</i> field format	367
Figure 12.6—Flush frame payload format.....	367
Figure 12.9—Mapping of organization-specific values.....	368
Figure 12.10—SAS notify frame payload format.....	368
Figure 12.11—Identifier value format	369
Figure 12.12—Identifier bit map format.....	369
Figure 12.13—PIRC frame payload format.....	370
Figure 12.14—PIRC frame status field.....	370
Figure 12.15—Available second classification.....	381
Figure 13.1—Management entities relationship to the ISO/IEC OSI reference model.....	386
Figure 13.2—Counter-measurement points	391
Figure 14.1—Undirected transmission	396
Figure 14.2—Directed transmission	396
Figure 14.3—SAS directed transmission	408
Figure 14.4—SAS undirected transmission.....	408
Figure 15.1—PIRC station types	418
Figure B.1—Reconciliation sublayer relationship to the ISO/IEC OSI reference model.....	440
Figure B.2—PRS-1 inputs and outputs.....	441
Figure B.3—PRS-1 signal mapping.....	442
Figure B.4—PRS-10 inputs and outputs.....	447
Figure B.5—PRS-10 signal mapping.....	448
Figure C.1—Reconciliation sublayer relationship to the ISO/IEC OSI reference model.....	457
Figure C.2—OSI and OIF reference model layers.....	457
Figure C.4—GRS frame structure.....	460
Figure C.3—SRS frame structure	460
Figure C.5—GFP core header.....	461
Figure C.6—GFP payload header	461
Figure C.7—SRS/GRS inputs and outputs using SPI-3(8).....	463
Figure C.8—8-bit SPI-3 transmit signal mapping	465
Figure C.9—SRS/GRS inputs and outputs using 32-bit SPI-3	469
Figure C.10—32-bit SPI-3 signal mappings.....	472

Figure C.11—SPI-4.1 single 64-bit interface signals	476
Figure C.12—64-bit SPI-4.1 signal mappings.....	479
Figure C.13—SPI-4.2 interface signals	482
Figure C.14—SPI-4.2 signal mappings	484
Figure E.1—Serial Crc16 reference model.....	643
Figure E.2—CRC16 calculations.....	644
Figure E.3—Protected header-field changes	644
Figure E.4—Illustration of CRC16 checks.....	645
Figure E.5—Serial CRC32 reference model	646
Figure E.6—Exchanged EXORSum calculations.....	647
Figure E.8—Illustration of CRC32 checks.....	648
Figure E.7—Data CRC stomping	648
Figure E.9—Parity generation model	649
Figure E.10—Illustration of fairness-frame checks.....	649
Figure F.1—Bridge architecture reference	652
Figure F.2—Loop-free and looped broadcast networks	653
Figure F.3—Local/remote end station transmission scenarios	654
Figure F.4—Asymmetric traffic flow issue	655
Figure F.6—Incorrect bridge filtering behavior	657
Figure F.5—RPR MAC handling of asymmetric traffic flows.....	657
Figure F.7—Correct bridge filtering behavior.....	659
Figure F.8—Bridge architecture model	661
Figure F.9—Service primitive mapping for frames from a bridge LLC or host	663
Figure F.10—Service primitive mapping for non-LLC frames from a bridge	664
Figure F.11—Enhanced service primitive mapping for frames from a bridge LLC or host	665
Figure F.12—Enhanced service primitive mapping for non-LLC frames from a bridge.....	666
Figure G.1—Provisioned classA bandwidth scenario	670
Figure G.2—ClassA credits fluctuations	671
Figure G.3—ClassA clamped-credit shaper behaviors.....	672
Figure I.1—Duplicate scenario 1: Unidirectional source bypass	688
Figure I.2—Duplicate scenario 2: Unidirectional wrapped source bypass.....	689
Figure I.3—Duplicate scenario 3: Bidirectional destination bypass	689
Figure I.4—Duplicate scenario 4: Bidirectional destination removals.....	690
Figure I.5—Duplicate scenario 5: Source and destination removals.....	690
Figure I.6—Reorder scenario 1: Protection switch during bidirectional flood	691
Figure I.7—Reorder scenario 2: Cascading failures during bidirectional flood.....	692
Figure I.8—Reorder scenario 3: Protection switching during unicast transmission	693
Figure I.9—Reorder scenario 4: Cascading failures during unidirectional flood.....	694
Figure J.1—Single queue spatial allocation.....	696
Figure J.2—Dual queue spatial allocation	697
Figure J.3—Cumulative station allocations.....	698
Figure K.1—Flushing a steered ring.....	704

**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

Part 17: Resilient packet ring (RPR) access method and physical layer specifications

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1. Overview

Resilient packet ring (RPR) is a metropolitan area network (MAN) technology supporting data transfer among stations interconnected in a dual-ring configuration.

1.1 Scope

This standard defines a resilient packet ring access protocol for use in local, metropolitan, and wide area networks, along with appropriate physical layer specifications for transfer of data packets at rates scalable to multiple gigabits per second.

1.2 Purpose

The standard defines a very high-speed network protocol that is optimized for packet transmission in resilient ring topologies needing service quality differentiation, efficient use of bandwidth, fair use of bandwidth, ease of use, and robustness.

1.3 RPR features

Key features of RPR that can distinguish it from other network interconnects, include the following:

- a) Addressing. Unicast, multicast, and simple broadcast data transfers are supported.
- b) Services. Multiple service qualities are supported, as listed below.
Per-service-quality flow-control protocols regulate traffic introduced by clients.
 - 1) ClassA. The allocated/guaranteed bandwidth has low circumference-independent jitter.
 - 2) ClassB. The allocated/guaranteed bandwidth has bounded circumference-dependent jitter. Allows for transmissions of excess information rate (EIR) bandwidths (with classC properties).
 - 3) ClassC. Provides best-effort services.
- c) Efficiency. Design strategies increase effective bandwidths beyond those of a broadcast ring.
 - 1) Concurrent transmission. Clockwise and counterclockwise transmissions can be concurrent.
 - 2) Bandwidth reallocation. Bandwidths can be reallocated on nonoverlapping segments.
 - 3) Bandwidth reclamation. Unused bandwidths can be reclaimed by opportunistic services.
 - 4) Spatial bandwidth reuse. Opportunistic bandwidths are reused on nonoverlapping segments.
 - 5) Temporal bandwidth reuse. Unused opportunistic bandwidth can be consumed by others.
- d) Fairness. Fairness ensures proper partitioning of opportunistic traffic.
 - 1) Weighted. Weighted fair access to available ring capacity.
 - 2) Simple. Point-of-congestion flow-control facilitates per-destination queuing in client.
 - 3) Detailed. The (optional) multi-choke fairness allows the client to selectively throttle its transmissions based on multiple congestion point indications.
- e) Plug-and-play. Automatic topology discovery and advertisement of station capabilities allow systems to become operational without manual intervention.
- f) Robustness. Multiple features support robust frame transmissions.
 - 1) Responsive. Service restoration time is less than 50 ms after a station or link failure.
 - 2) Lossless. Queue and shaper specifications avoid frame loss in normal operation.
 - 3) Tolerant. Fully distributed control architecture eliminates single points of failure.
 - 4) OAM. Operations, administration, and maintenance support service provider environments.

RPR supports up to 255 station attachments and is optimized for rings with a maximum circumference of 2000 km.

NOTE—The 2000 km figure previously mentioned is a design goal and not a specific physical constraint.¹

1.4 Document structure

This document is Part 17 of IEEE Std 802[®],² providing the RPR medium access control (MAC) and physical layer (PHY) specifications. All of the following material is included within the scope of this standard except those items explicitly identified as informative:

- a) Clause 1: Overview
- b) Clause 2: Normative references (provisions of this standard through reference in the text)
- c) Clause 3: Terms, definitions, and notation
- d) Clause 4: Abbreviations and acronyms
- e) Clause 5: Architecture overview

¹Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

²Information on references can be found in Clause 2.

- f) Clause 6: Medium access control (MAC) service and reference model
- g) Clause 7: Medium access control datapath
- h) Clause 8: MAC physical interface
- i) Clause 9: Frame formats
- j) Clause 10: Fairness
- k) Clause 11: Topology discovery and protection
- l) Clause 12: Operations, administration, and maintenance (OAM)
- m) Clause 13: Layer management entity interface
- n) Clause 14: Spatially aware sublayer
- o) Clause 15: Protected inter-ring connection
- p) Annex A: (informative): Bibliography
- q) Annex B: (normative): PacketPHY reconciliation sublayers
- r) Annex C: (normative): SONET/SDH reconciliation sublayers
- s) Annex D: (normative): SNMP MIB definitions
- t) Annex E: (normative): CRC and parity calculations
- u) Annex F: (informative): 802.1D and 802.1Q bridging conformance
- v) Annex G: (informative): Implementation guidelines
- w) Annex H: (informative): C-code illustrations of CRC computations
- x) Annex I: (informative): Datapath scenarios
- y) Annex J: (informative): Spatial indications and shaping
- z) Annex K: (informative): Client-based OAM operations using echo and flush

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used; therefore, each referenced document is cited in text, and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI T1.105.01-2000, Synchronous Optical Network (SONET)—Automatic Protection Switching.³

EIA/JEDEC JESD8-B, Interface Standard for Nominal 3V/3.3V Supply Digital Integrated Circuits.⁴

IEEE Std 802-2001, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.^{5, 6}

IEEE Std 802.1D™-2004, Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 3: Media Access Control (MAC) Bridges.

IEEE Std 802.1Q™-2005, IEEE Standards for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks.

IEEE Std 802.3™-2008, Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.

IETF RFC 1662: PPP in HDLC-Like Framing, W. Simpson, July 1994.⁷

IETF RFC 2578, STD 58: Structure of Management Information Version 2 (SMIv2), K. McCloghrie et al., April 1999.

IETF RFC 2579, STD 58: Textual Conventions for SMIv2, K. McCloghrie et al., April 1999.

IETF RFC 2580, STD 58: Conformance Statements for SMIv2, K. McCloghrie et al., April 1999.

IETF RFC 2615: PPP over SONET/SDH, A. Malis, W. Simpson, June 1999.

IETF RFC 2863: The Interfaces Group MIB, K. McCloghrie, F. Kastenholz, June 2000.

IETF RFC 3291: Textual Conventions for Internet Network Addresses, M. Daniele et al., May 2002.

ISO/IEC 2382-9:1995, Information technology—Vocabulary—Part 9: Data communication.⁸

³ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁴EIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

⁵The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

⁶IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854-4141, USA (<http://standards.ieee.org/>).

⁷IETF publications are available via the World Wide Web at <http://www.ietf.org>.

⁸ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). ISO/IEC publications are also available in the United States from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>). Electronic copies are available in the United States from the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

ISO/IEC 9899:1999, Programming languages—C.

ITU-T Recommendation G.707, Network Node Interface for the Synchronous Digital Hierarchy (SDH).⁹

ITU-T Recommendation G.783, Characteristics of Synchronous Digital Hierarchy (SDH) Equipment Functional Blocks.

ITU-T Recommendation G.7041, Generic Framing Procedure.

ITU-T Recommendation X.85/Y.1321, IP over SDH using LAPS.

OIF System Packet Interface Level 3 (SPI-3): OC48 System Interface for Physical and Link Layer Devices. Implementation agreement: OIF-SPI3-01.0, June 2000.¹⁰

OIF System Packet Interface Level 4 Phase 1 (SPI-4.1): OC192 System Interface for Physical and Link Layer Devices. Implementation agreement: OIF-SPI4-01.0, April 2001.

OIF System Packet Interface Level 4 Phase 2 (SPI-4.2): OC192 System Interface for Physical and Link Layer Devices. Implementation agreement: OIF-SPI4-02.0, January 2001.

Telcordia Technologies GR-253-CORE, Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria (A Module of TSGR, FR-440). Issue 3. September 2000.

⁹ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>).

¹⁰Optical Internetworking Forum (OIF) publications are available via the World Wide Web at <http://www.oiforum.com>, under “Technical Work” and “OIF Implementation Agreements”.

3. Terms, definitions, and notation

3.1 Conformance levels

Several key words are used to differentiate between different levels of requirements and options, as described in this subclause.

3.1.1 may: Indicates a course of action permissible within the limits of the standard with no implied preference (“may” means “is permitted to”).

3.1.2 shall: Indicates mandatory requirements to be strictly followed in order to conform to the standard and from which no deviation is permitted (“shall” means “is required to”).

3.1.3 should: An indication that among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited (“should” means “is recommended to”).

3.2 Terms and definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms & Definitions* should be consulted for terms not defined in this clause.¹¹

3.2.1 adaptation sublayer: A protocol sublayer that exists for the purpose of converting data from one format to another.

3.2.2 agent: A network management entity (NME) used to configure a station and/or collect data describing the operation of that station.

3.2.3 aggressive rate adjustment: A method of rate adjustment in which the rates can be changed without significant delay and amounts of rate change are not highly damped.

3.2.4 allocated bandwidth: Bandwidth that may be subject to reclamation, but that is to be made available to the allocating station when requested. A class of traffic is said to be allocated when the limits associated with that class are determined by a network operator's engineering/operations department. There are two types of allocated bandwidth: reserved and reclaimable. Allocated bandwidth refers to the amount of bandwidth on a ringlet that provides the necessary capacity for classes of committed rate services.

3.2.5 available capacity: Ring capacity not required to support allocated service and, consequently, available to support opportunistic service.

3.2.6 best-effort: Not associated with an explicit service guarantee.

3.2.7 bidirectional flooding: A frame forwarding transfer involving sending two flooding frames, one on each ringlet (ringlet0 and ringlet1), where each frame is directed to distinct adjacent stations.

3.2.8 bit error ratio (BER): The ratio of the number of bits received in error to the total number of bits transmitted.

¹¹The *IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

3.2.9 bridge: A functional unit interconnecting two or more networks at the data link layer of the OSI reference model.

3.2.10 broadcast: The act of sending a frame addressed to all stations on the network.

3.2.11 broadcast address: A group address that consists of all-ones and identifies all of the stations in a network.

3.2.12 cleave point: The point, between stations, at which a ring is logically divided.

3.2.13 closed ring: An intact ring (i.e., one that has not been cut) that provides a complete path all the way around the ring. A closed ring contains no detected edges.

3.2.14 committed information rate (CIR): The rate, averaged over a minimum interval of time, at which the network agrees to transfer data.

3.2.15 congestion: The state of a ringlet or station determined by calculation of the MAC fairness algorithm that causes restriction or regulation of the addition of fairness eligible traffic to the ring.

3.2.16 congestion domain: The set of contiguous links associated with a ringlet that causes congestion at a common congestion point. This is also the set of links between the congestion head and the congestion tail.

3.2.17 congestion head: The furthest downstream station of a congestion domain. This is the station immediately upstream of the congestion point.

3.2.18 congestion point: The transmit link of a station experiencing congestion and not contributing to downstream congestion. This link is immediately downstream of the congestion head.

3.2.19 congestion tail: The furthest upstream station of a congestion domain.

3.2.20 conservative: An algorithm that tends to exhibit an overdamped transient response.

3.2.21 conservative rate adjustment: A method of rate adjustment in which the rate is generally not changed until sufficient time has passed for the effect of any previous rate adjustment to be observed and whose amount of change exhibits significant dampening and hysteresis.

3.2.22 cyclic redundancy check (CRC): A specific type of frame check sequence computed using a generator polynomial.

3.2.23 destination station: A station to which a frame is addressed.

3.2.24 destination stripping: The removal of frames from the ring by the destination station.

3.2.25 directed transmission: Transmission of a frame to a single station on the medium.

3.2.26 downstream: The direction of data flow on a ringlet.

3.2.27 dual-ring: A ring composed of two ringlets sharing the same set of stations such that the order of station traversal for data frames on one ringlet is exactly opposite that of the other ringlet when no faults exist on the ring.

3.2.28 end-to-end delay: The time required for the transfer of a frame between source and destination stations as measured from the start of frame transmission to the start of frame reception at the respective MAC service interfaces.

3.2.29 excess information rate: The rate at which the network transfers data in excess of the committed information rate when no network congestion exists.

3.2.30 fairness: The property that for any given link on the ring, every source receives an equal proportion of fairness eligible capacity. If all sources have equal weights, then all sources have substantially equal access to the available capacity of all links.

3.2.31 fairness eligible: A quality of a frame that indicates if it is subject to the fairness algorithm.

3.2.32 fairness round-trip time (FRTT): The time that it takes for a fairness value to propagate from the head of a congestion domain to the tail of the same congestion domain and for the first affected data frame to be sent from the tail of the congestion domain to be received by the head of the congestion domain.

3.2.33 fair rate: A rate having the property that one station is prevented from utilizing a disproportionate share of available ringlet capacity with respect to other stations on the ringlet.

3.2.34 flooding: The act of transmitting a frame such that all stations on the ring receive the frame once.

3.2.35 flooding scope: The number of hops that a frame can travel (around the ring) from a given source station to a destination station associated with a given ringlet.

3.2.36 flow control: A method of congestion control in which a station communicates to another station or stations, information intended to regulate the transmission of frames.

3.2.37 frame: The MAC sublayer protocol data unit (PDU).

3.2.38 frame check sequence (FCS): The field immediately preceding the closing delimiter of a frame, allowing the detection of payload errors by the receiving station.

3.2.39 gigabit media independent interface (GMII): The interface between the reconciliation sublayer and the physical coding sublayer (PCS) for 1000 Mb/s operation.

3.2.40 group address: An address that identifies a group of stations on a network.

3.2.41 header error check (HEC): A field appended to the frame header for the purpose of detecting, and optionally correcting, errors in the transmission of the header portion of the frame.

3.2.42 hop-count: The number of hops traversed by data circulating between stations on the ring.

3.2.43 in flight: Transmitted by the source MAC and not yet received by the (final) destination MAC.

3.2.44 in transit: Received by a MAC's PHY and not yet transmitted by the MAC's other PHY.

3.2.45 individual address: An address that identifies a particular station on a network.

3.2.46 jitter: The variation in delay associated with the transfer of frames between two points.

3.2.47 keepalive: An exchange of messages allowing verification that communication between stations is active.

3.2.48 layer management entity (LME): The entity within a protocol layer that performs local management of that layer. This entity provides information about the layer, effects control over it, and indicates the occurrence of certain events within it.

NOTE—The term *LME* can be prefixed with the name of the layer, for example, MAC LME (MLME).

3.2.49 link: A unidirectional channel connecting adjacent stations on a ringlet.

3.2.50 link rate: The data rate with which a MAC communicates with its adjacent MAC entity.

3.2.51 line rate: The rate at which a PHY transfers data on the attached physical medium.

3.2.52 local area network (LAN): A communications network designed for a small geographic area, typically not exceeding a few kilometers in extent, and characterized by moderate to high data transmission rates, low delay, and low bit error rates.

3.2.53 logical link control (LLC) sublayer: That part of the data link layer that supports media independent data link functions, and uses the services of the MAC sublayer to provide services to the network layer.

3.2.54 loop round-trip time (LRTT): The time that it takes for a control frame or a data frame to be sent from one station to another station and back to the original station.

3.2.55 MAC client: The layer entity that invokes the MAC service interface.

3.2.56 MAC layer management entity (MLME): *See: LME.*

3.2.57 major priority inversion: Any reclamation-caused effect that violates the guarantee of any equal or higher class.

3.2.58 management information base (MIB): A repository of information to describe the operation of a specific network device.

3.2.59 maximum transfer unit (MTU): The largest frame (comprising payload and all header and trailer information) that can be transferred across the network.

3.2.60 medium (plural: media): The material on which information signals are carried, e.g., optical fiber, coaxial cable, and twisted-wire pairs.

3.2.61 medium access control (MAC) sublayer: The portion of the data link layer that controls and mediates the access to the network medium.

NOTE—In this standard, the MAC sublayer comprises the MAC datapath sublayer and the MAC control sublayer.

3.2.62 metropolitan area network (MAN): A network interconnecting individual stations and/or LANs, and spanning an area typically occupied by a city.

NOTE—A MAN generally operates at a higher speed than the networks interconnected and crosses network administrative boundaries.

3.2.63 minor priority inversion: A small reclamation-caused effect on any equal or higher service class that does not violate the service guarantees of that class.

3.2.64 multicast: Transmission of a frame to stations specified by a group address.

3.2.65 multicast address: A group address that is not a broadcast address, i.e., is not all-ones, and identifies some subset of stations on the network.

3.2.66 multi-choke: The characteristic of an algorithm, related to the visibility of multiple points of congestion on a ringlet.

3.2.67 network: A set of communicating stations and the media and equipment providing connectivity among the stations.

3.2.68 non-revertive mode: A mode of operation of a station in which, upon clearing of all failures on one of its spans, the station remains in a wait to restore protection state until the wait to restore condition is preempted by a higher priority protection condition elsewhere on the ring.

3.2.69 open ring: A ring that has been cut, thereby preventing it from completing a full loop. It has at least one detected edge.

3.2.70 opposing ringlet: A ringlet whose traffic circulates in the direction opposite that of a given ringlet.

3.2.71 packet: A generic term for a PDU associated with a layer-entity above the MAC sublayer.

3.2.72 passthrough: A condition of a MAC such that frames pass through it as if it were operating as a link between the stations on either side of it.

3.2.73 permissive: Frame transmission that permits (within a conversation) frame reorder and duplication while recovering from failures on the ring, and frame reorder when changing between undirected and directed transmission.

3.2.74 physical layer (PHY): The layer responsible for interfacing with the transmission medium. This includes conditioning signals received from the MAC for transmitting to the medium and processing signals received from the medium for sending to the MAC.

3.2.75 plug-and-play: The requirement that a station perform transit, strip, and ring control activities without operator intervention (except for any intervention needed for connection to the ring). The station can additionally copy and insert frames.

3.2.76 port: A generic term identifying a point of access to a device or service.

3.2.77 primary protection group member: The PIRC protection group member with higher protection priority.

3.2.78 protected inter-ring connection (PIRC) mate station: The other station on the same ring performing the interconnect functionality from that ring to the same destination ring(s).

3.2.79 protected inter-ring connection (PIRC) station: A station that provides connectivity between rings and exchanges PIRC messages with other similarly interconnected devices.

3.2.80 protection group: A collection of two PIRC stations on the same ring performing the interconnect functionality from that ring to the same destination rings.

3.2.81 protection group member: One of the PIRC stations in a protection group.

3.2.82 protection switch event: A received protection control frame that causes the local topology and status database to be updated/changed.

3.2.83 protocol data unit (PDU): Information delivered as a unit between peer layer entities that contains control information and, optionally, data.

3.2.84 protocol implementation conformance statement (PICS): A statement of which capabilities and options have been implemented for a given Open Systems Interconnection (OSI) protocol.

3.2.85 rate: The number of bytes transferred per time.

NOTE—In this standard, rate is measured in bytes per *ageCoef*agingIntervals when nothing else is stated explicitly.

3.2.86 reconciliation sublayer (RS): A sublayer that provides a mapping between the PHY service interface and the medium independent interface of the PHY.

3.2.87 relaxed: Frame transmission that permits frame reorder and duplication within a conversation when recovering from failures on the ring.

3.2.88 remote address: Any unicast address that is not a ring local address.

3.2.89 replicated frame: A frame that is copied for sending bidirectionally on both ringlets.

3.2.90 reserved bandwidth: The amount of bandwidth that is to be kept available (i.e., is not subject to reclamation). This represents the subset of allocated bandwidth that is not dynamically reclaimable by a fairness algorithm.

3.2.91 reclaimable bandwidth: That subset of allocated bandwidth that is dynamically reclaimable by a fairness algorithm.

3.2.92 revertive mode: A mode of operation of a station in which, upon clearing of all failures on one of its spans, the station enters a wait to restore protection state, followed by an entry to the idle state after expiration of the wait to restore time.

3.2.93 ring: The collection of stations and links forming a resilient packet ring.

3.2.94 ring local address: The station address of one station on the ring.

3.2.95 ring round-trip time (RRTT): The time that it takes for a control frame or a data frame to be sent around an entire ring.

3.2.96 ringlet: A closed unidirectional path formed by an ordered set of stations and interconnecting links, such that each station has exactly one link entering the station and one link exiting the station.

3.2.97 scoped transmission: A method of transmitting a multicast frame with a TTL value that limits its reach to the furthest station that requires the frame.

3.2.98 secondary protection group member: The PIRC protection group member with lower protection priority.

3.2.99 service class¹²: The categorization of MAC service by delay bound, relative priority, data rate guarantee, or similar distinguishing characteristics.

3.2.100 service data unit (SDU): Information delivered as a unit between adjacent layer entities, possibly also containing a PDU of the upper layer.

¹²*Service class* and *traffic class* are synonyms for the purposes of this standard. *Service class* is the preferred term.

3.2.101 service guarantee: Delay or jitter bounds or bandwidth guaranteed for an instance of a service class.

3.2.102 shaper: A device that converts an arbitrary traffic flow to a smoothed traffic flow at a specified data rate.

3.2.103 single-choke: The characteristic of an algorithm, related to the visibility of only a single point of congestion on a ringlet. A MAC that deploys this type of fairness algorithm at each station has visibility of no more than one point of congestion on a ringlet.

3.2.104 source station: The station that originates a frame with respect to the ring.

3.2.105 source stripping: The removal of frames by the source station after circulation on the ring.

3.2.106 spatial reuse: The concurrent transfer of independent traffic on nonoverlapping portions of a ringlet.

3.2.107 station: A device attached to a network for the purpose of transmitting and receiving information on that network.

3.2.108 strict: Frame transmission that prevents frame reorder and duplication within a conversation.

3.2.109 strict data frame: A frame having its *so* (strict order) bit set.

3.2.110 topology: The arrangement of links and stations forming a network, together with information on station attributes.

3.2.111 traffic class: *See:* **service class**.

3.2.112 transfer: The movement of an SDU from one layer to an adjacent layer. Also used generally to refer to any movement of information from one point to another in the network.

3.2.113 transit delay: The delay experienced by a frame transiting a station on the ringlet.

3.2.114 transit queue: A queue maintained for the purpose of storing a transit frame at a station until that frame has permission to continue transit of the ringlet.

3.2.115 transmit (transmission): The action of a station placing a frame on the medium.

3.2.116 transparent bridging: A bridging mechanism that is transparent to the end stations.

3.2.117 unicast: The act of sending a frame addressed to a single station.

3.2.118 undirected transmission: Transmission of a frame on to the medium using flooding.

3.2.119 unidirectional flooding: A frame forwarding transfer involving sending a flooding frame in the downstream direction of one ringlet, with that frame being directed to its sending station.

3.2.120 unknown unicast: A unicast frame for which the location of its destination is unknown.

3.2.121 unallocated bandwidth: Bandwidth that is not allocated to any provisioned service.

3.2.122 unreserved: A designation for traffic capacity that is not reserved. This is also a designation for the traffic occupying that bandwidth. In addition, unreserved bandwidth may or may not be allocated bandwidth.

3.2.123 upper layers: The collection of protocol layers above the data-link layer.

3.2.124 virtual LAN (VLAN): A subset of the active topology of a bridged local area network.

3.2.125 weighted fairness: A class of fairness algorithm that allows the assignment of unequal shares of available ring capacity. For the purposes of this standard, any reference to fairness is to be taken to imply weighted fairness. An alternative definition is the use of a weight associated with each fairness instance, allowing a station to add at a higher or lower rate than other stations without violating fairness objectives. This behavior can be effectively disabled by assigning equal weights to fairness instances.

3.2.126 weighted fair share: The ratio of the weight of a station to the sum of the weights of stations active on the ringlet.

3.3 Service definition method and notation

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher (sub)layer. Abstract services are specified in this standard by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation (see Figure 3.1).

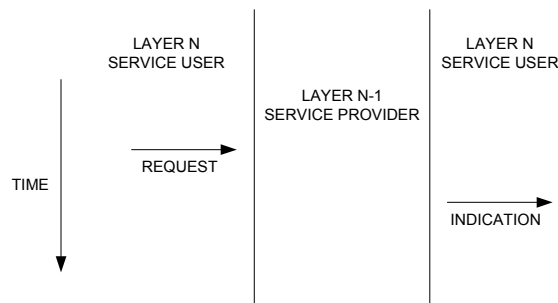


Figure 3.1—Service definitions

Specific implementations can also include provisions for interface interactions that have no direct end-to-end effects. Examples of such local interactions include interface flow control, status requests and indications, error notifications, and layer management. Specific implementation details are omitted from this service specification, because they differ from implementation to implementation and because they do not impact the peer-to-peer protocols.

3.3.1 Classification of service primitives

Primitives are of two generic types:

- a) **REQUEST.** The request primitive is passed from layer N to layer N-1 to request that a service be initiated.
- b) **INDICATION.** The indication primitive is passed from layer N-1 to layer N to indicate an internal layer N-1 event that is significant to layer N. This event can be logically related to a remote service request, or it can be caused by an event internal to layer N-1.

The service primitives are an abstraction of the functional specification and the user-layer interaction. The abstract definition does not contain local details of the user-provider interaction. For instance, it does not

indicate the local mechanism that allows a user to indicate that it is awaiting an incoming call. Each primitive has a set of zero or more parameters, representing data elements that are passed to qualify the functions invoked by the primitive. Parameters indicate information available in a user-provider interaction. In any particular interface, some parameters can be explicitly stated (even though not explicitly defined in the primitive) or implicitly associated with the service access point. Similarly, in any particular protocol specification, functions corresponding to a service primitive can be explicitly defined or implicitly available.

3.4 State machines

The operation of a protocol can be described by subdividing the protocol into a number of interrelated functions. The operation of the functions can be described by state machines. Each state machine represents the domain of a function and consists of a group of connected, mutually exclusive states. Only one state of a function is active at any given time. A transition from one state to another is assumed to take place in zero time (i.e., no time period is associated with the execution of a state), based on some condition of the inputs to the state machine.

The state machines contain the authoritative specification of the functions they depict. When apparent conflicts between descriptive text and state machines arise, the order of precedence shall be formal state tables first, followed by the descriptive text, over any explanatory figures. This does not override, however, any explicit description in the text that has no parallel in the state tables.

The models presented by state machines are intended as the primary specifications of the functions to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, whereas any realistic implementation might place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that has to match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

3.4.1 State table notation

3.4.1.1 Continuously executed state tables

State machines may be represented in tabular form. The table is organized into two columns: a left-hand side representing all of the possible states of the state machine and all of the possible conditions that cause transitions out of each state, and the right-hand side giving all of the permissible next states of the state machine as well as all of the actions to be performed in the various states, as illustrated in Table 3.1. The syntax of the expressions follows standard C notation (see 3.14). No time period is associated with the transition from one state to the next.

Table 3.1—State table notation example

Current state		Row	Next state	
state	condition		action	state
START	sizeofMacControl > spaceInPTQ	1	—	START
	passM == 0	2		
	—	3	TransmitFromControlQueue();	FINAL
FINAL	SelectedTransferCompletes()	4	—	START
	—	5	—	FINAL

Row 3.1-1: Do nothing if the size of the queued MAC control frame is larger than the PTQ space.

Row 3.1-2: Do nothing in the absence of MAC control transmission credits.

Row 3.1-3: Otherwise, transmit a MAC control frame.

Row 3.1-4: When the transmission completes, start over from the initial state (i.e., START).

Row 3.1-5: Until the transmission completes, remain in this state.

Each combination of current state, next state, and transition condition linking the two is assigned to a different row of the table. Each row of the table, read left to right, provides the name of the current state; a condition causing a transition out of the current state; an action to perform (if the condition is satisfied); and, finally, the next state to which the state machine transitions, but only if the condition is satisfied. The symbol “—” signifies the default condition (i.e., operative when no other condition is active) when placed in the condition column, and it signifies that no action is to be performed when placed in the action column. Conditions are evaluated in order, top to bottom, and the first condition that evaluates to a result of TRUE is used to determine the transition to the next state. If no condition evaluates to a result of TRUE, then the state machine remains in the current state. The starting or initialization state of a state machine is always labeled “START” in the table (although it need not be the first state in the table). Every state table has such a labeled state.

Each row of the table is preferably provided with a brief description of the condition and/or action for that row. The descriptions are placed after the table, and linked back to the rows of the table using numeric tags.

3.4.1.2 Called state tables

A RETURN state is the terminal state of a state machine that is intended to be invoked by another state machine, as illustrated in Table 3.2. Once the RETURN state is reached, the state machine terminates execution, effectively ceasing to exist until the next invocation by the caller, at which point it begins execution again from the START state. State machines that contain a RETURN state are considered to be instantiated only when they are invoked. They do not have any persistent (static) variables.

Table 3.2—Called state table notation example

Current state		Row	Next state	
state	condition		action	state
START	sizeofMacControl > spaceInPTQ	1	—	FINAL
	passM == 0	2		
	—	3	TransmitFromControlQueue();	RETURN
FINAL	MacTransmitError();	4	errorDefect = TRUE	RETURN
	—	5	—	

Row 3.2-1: The size of the queued MAC control frame is less than the PTQ space.

Row 3.2-2: In the absence of MAC control transmission credits, no action is taken.

Row 3.2-3: MAC control transmissions have precedence over client transmissions.

Row 3.2-4: If the transmission completes with an error, set an error defect indication.

Row 3.2-5: Otherwise, no error defect is indicated.

3.5 Arithmetic and logical operators

In addition to commonly accepted notation for mathematical operators, Table 3.3 summarizes the symbols used to represent arithmetic and logical (boolean) operations. Note that the syntax of operators follows standard C notation (see 3.14).

Table 3.3—Special symbols and operators

Printed character	Meaning
&&	Boolean AND
	Boolean OR
!	Boolean NOT (negation)
&	Bitwise AND
	Bitwise OR
^	Bitwise XOR
<=	Less than or equal to
>=	Greater than or equal to
==	Equal to
!=	Not equal to
=	Assignment operator
//	Comment delimiter

3.6 Numerical representation

Decimal, hexadecimal, and binary numbers are used within this document. For clarity, decimal numbers are generally used to represent counts, hexadecimal numbers are used to represent addresses, and binary numbers are used to describe bit patterns within binary fields.

Decimal numbers are represented in their usual 0, 1, 2, ... format. Hexadecimal numbers are represented by a string of one or more hexadecimal (0-9,A-F) digits followed by the subscript 16, except in C-code contexts, where they are written as 0x123EF2, etc. Binary numbers are represented by a string of one or more binary (0,1) digits, followed by the subscript 2. Thus, the decimal number “26” may also be represented as “1A₁₆” or “11010₂”.

MAC addresses and OUI/EUI values are represented as strings of 8-bit hexadecimal numbers separated by hyphens and without a subscript, as for example, “01-80-C2-00-00-15” or “AA-55-11”.

3.7 Field notations

3.7.1 Use of italics

All field names or variable names (such as *level* or *myMacAddress*) and subfields within variables (such as *thisState.level*) are italicized within text, figures, and tables to avoid confusion between such names and similarly spelled words without special meanings. A variable or field name that is used in a subclause

heading or a figure or table caption is also italicized. Variable or field names are not italicized within C code, however, because their special meaning is implied by their context. Names used as nouns (e.g., subclassA0) are also not italicized.

3.7.2 Field conventions

This document describes values that are packetized or MAC-resident, such as those illustrated in Table 3.4.

Table 3.4—Names of fields and subfields

Name	Description
<i>newCRC</i>	Field within a register or frame
<i>thisState.level</i>	Subfield within field <i>thisState</i>
<i>thatState.rateC[n].c</i>	Subfield within array element <i>rateC[n]</i>

Run-together names (e.g., *thisState*) are used for fields because of their compactness when compared with equivalent underscore-separated names (e.g., *this_state*). The use of multiword names with spaces (e.g., “This State”) is avoided to prevent confusion between commonly used capitalized key words and the capitalized word used at the start of each sentence.

A subfield of a field is referenced by suffixing the field name with the subfield name, separated by a period. For example, *thisState.level* refers to the subfield *level* of the field *thisState*. This notation can be continued to represent subfields of subfields (e.g., *thisState.level.next* is interpreted to mean the subfield *next* of the subfield *level* of the field *thisState*).

Two special field names are defined for use throughout this standard. The name *frame* is used to denote the data structure comprising the complete MAC sublayer PDU. Any valid element of the MAC sublayer PDU can be referenced using the notation *frame.xx* (where *xx* denotes the specific element); thus, for instance, *frame.ttl* is used to indicate the *ttl* element of an RPR frame. In addition, the notation *MIB.xx* is used to reference an attribute of the Management Information Base defined within this standard; hence, *MIB.rprIfTable.rprIfEntry.rprIfIndex* references the interface index attribute of the RPR MIB.

Unless specifically specified otherwise, reserved fields are reserved for the purpose of allowing extended features to be defined in future revisions of this standard. For devices conforming to this version of this standard, nonzero reserved fields are not generated; values within reserved fields (whether zero or nonzero) are to be ignored.

3.7.3 Field value conventions

This document describes values of fields. For clarity, names can be associated with each of these defined values, as illustrated in Table 3.5. A symbolic name, consisting of uppercase letters with underscore separators, allows other portions of this document to reference the value by its symbolic name, rather than a numerical value.

sequence of ordered bytes, where the first through last bytes correspond to the most significant through least significant portions of the multi-byte field, and the MSB of each byte is drawn to be on the left-hand side.

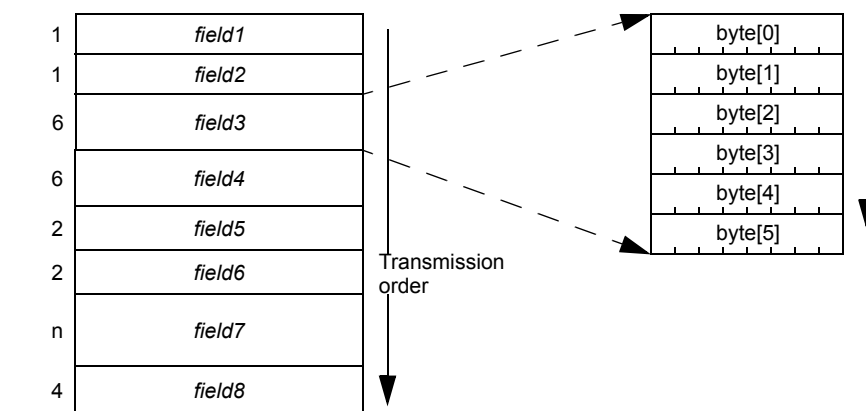


Figure 3.3—Byte-sequential field format illustrations

NOTE—Only the left-hand diagram in Figure 3.3 is required for representation of byte-sequential formats. The right-hand diagram is provided in this description for explanatory purposes only, for illustrating how a multi-byte field within a byte-sequential representation is expected to be ordered. The tag “Transmission order” and the associated arrows are not required to be replicated in the figures.

3.10 Left-to-right ordering

In many cases, bit fields within byte or multibyte objects are expanded in a horizontal fashion, as illustrated in the right side of Figure 3.4. The fields within these objects are illustrated as follows: Left-to-right is the byte transmission order; the left-through-right bits are the most significant through least significant bits, respectively.

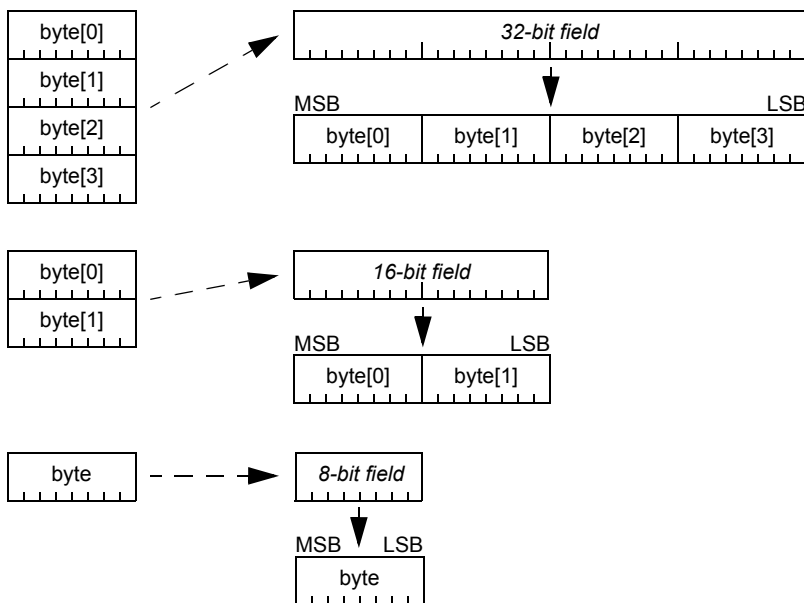


Figure 3.4—Multi-byte field illustrations

NOTE—Only the right-hand diagrams in Figure 3.4 are used within normative clauses. The left-hand diagrams are provided in this description for explanatory purposes only.

For consistency with bit and byte ordering conventions, bits are numbered in a left-to-right order. Depending on the interconnect, this RPR bit-numbering order may or may not differ from the physical layer bit transmission ordering.

3.11 Representation of MAC addresses

The format of MAC address fields within frames consists of OUI and *dependentID* fields and is illustrated for organization-specific frames in Figure 3.5.

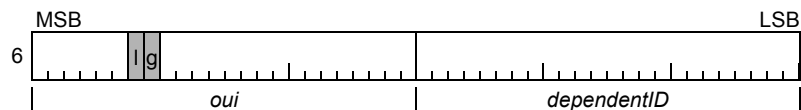


Figure 3.5—Organization-specific *controlDataUnit* field format

3.11.1 *oui*: A 24-bit organizationally unique identifier (OUI) field, used for the purpose of identifying the organization supplying the 24-bit *dependentID*. For clarity, the locations of the universally/locally administered and individual/group address bits are illustrated by the shaded *l* and *g* fields, respectively.

3.11.2 *dependentID*: A 24-bit field supplied by the *oui*-specified organization. Within this context, the *dependentID* is unique within a given organization; hence, the concatenation of the *oui* and *dependentID* provide a globally unique identifier.

An example of the mapping of actual values to the *oui/dependentID* fields is shown in Figure 3.6.

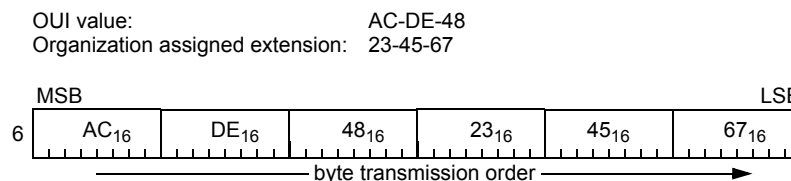


Figure 3.6—48-bit MAC address format

3.12 Mapping of numeric data values to fields

The mapping of hexadecimal and binary values to frame fields is illustrated in Figure 3.7.

The byte-sequential format of Figure 3.7-a is represented by Figure 3.7-b when transferred over a 32-bit data path. As an example, arbitrary numeric values have been assigned to the fields in Figure 3.7-b, and these values are represented in hexadecimal format in Figure 3.7-c and binary format in Figure 3.7-d.

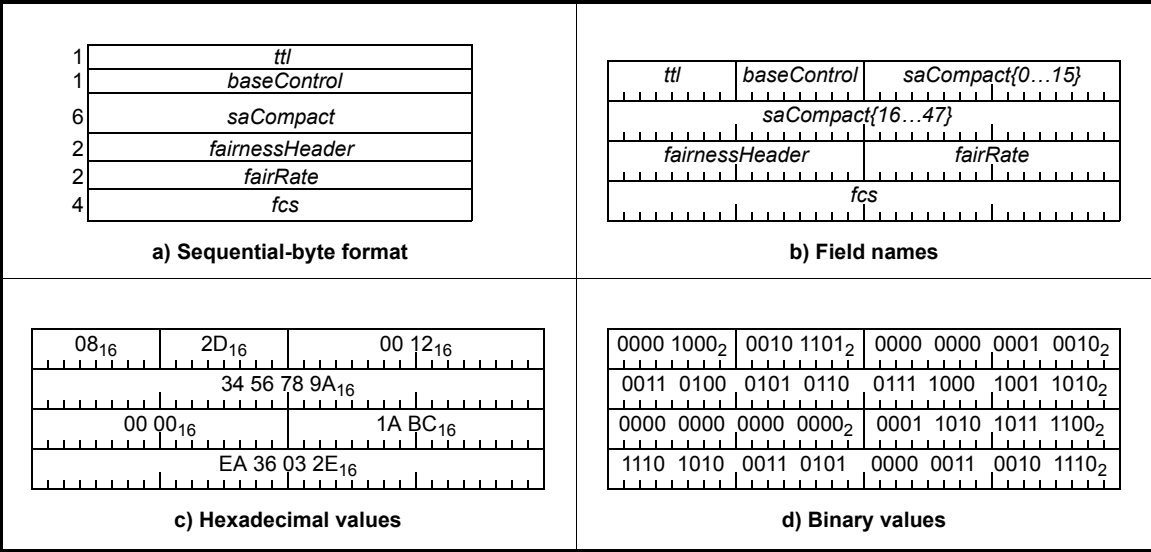


Figure 3.7—Illustration of fairness-frame structure

3.13 Informative notes

Informative notes are used in this standard to provide guidance to implementers and to supply useful background material. Such notes never contain normative information, and implementers are not required to adhere to any of their provisions. An example of such a note follows.

NOTE—This is an example of an informative note.

3.14 Conventions for C code used in state machines

Many of the state machines contained in this standard utilize C code functions, operators, expressions, and structures for the description of their functionality. Conventions for such C code can be found in Annex H.

3.15 Ringlet orientation conventions

By default, figures containing illustrations of RPR interfaces depict the east receive interface to ringlet0 on the upper left, the east transmit interface to ringlet0 on the upper right, the west receive interface to ringlet1 on the lower right, and the west transmit interface to ringlet1 on the lower left.

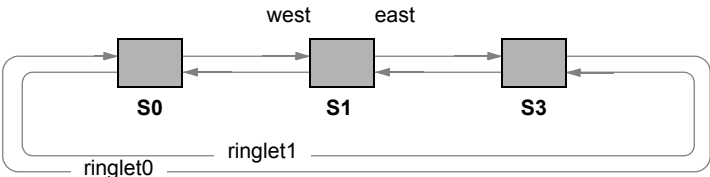


Figure 3.8—Ringlet orientation conventions

4. Abbreviations and acronyms

This standard contains the following abbreviations and acronyms:

BER	bit error ratio
CIR	committed information rate
CRC	cyclic redundancy check
dLOC	loss of continuity failure defect
EIR	excess information rate
EISS	enhanced internal sublayer service
FCS	frame check sequence
FDB	filtering database
FID	FDB identifier
FIFO	first in first out
FRTT	fairness round-trip time
FS	forced switch
GFP	generic framing procedure
GMII	gigabit media independent interface
GRS	GFP reconciliation sublayer
HDLC	high-level data link control
HEC	header error check
IANA	Internet Assigned Numbers Authority
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
ISS	internal sublayer service
ITU	International Telecommunication Union
LAN	local area network
LAPS	link access procedure—SDH
LCP	link control protocol
LLC	logical link control
LME	layer management entity
LOC	loss of continuity failure
LRTT	loop round-trip time
LSB	least significant bit
LVDS	low-voltage differential signals
LVTTL	low-voltage transistor-transistor logic
MAC	medium access control
MAN	metropolitan area network
MCFF	multi-choke fairness frame
MIB	management information base
MII	medium independent interface
MLME	MAC layer management entity
MS	manual switch
MSB	most significant bit
MSTI	Multiple Spanning Tree Instance
MTU	maximum transfer unit
OAM	operations, administration, and maintenance
OIF	Optical Internetworking Forum
OSI	open systems interconnect
PCS	physical coding sublayer
PDU	protocol data unit
PG	protection group

PGM	protection group member
PHY	physical layer
PICS	protocol implementation conformance statement
PIRC	protected inter-ring connection
PLME	physical layer management entity
PMA	physical medium attachment
PMD	physical medium dependent
PPM	parts per million
PPP	point to point protocol
PRS-1	1 Gb/s packetPHY reconciliation sublayer
PRS-10	10 Gb/s packetPHY reconciliation sublayer
PTQ	primary transit queue
RFC	request for comment
RPR	resilient packet ring
RS	reconciliation sublayer
RRTT	ring round-trip time
SAS	spatially aware sublayer
SCFF	single-choke fairness frame
SD	signal degrade
SDB	SAS database
SDH	synchronous digital hierarchy
SDU	service data unit
SF	signal fail
SME	station management entity
SNMP	simple network management protocol
SONET	synchronous optical network
SPI	system packet interface
SPI-3	System Packet Interface Level 3
SPI-4.1	System Packet Interface Level 4 Phase 1
SPI-4.2	System Packet Interface Level 4 Phase 2
SRS	SONET/SDH reconciliation sublayer
STQ	secondary transit queue
TP	topology and protection
VID	VLAN identifier
VLAN	virtual LAN
WAN	wide area network
WIS	WAN interface sublayer
WTR	wait to restore
XAUI	10 Gb attachment unit interface
XGMII	10 Gb media independent interface
XGXS	XGMII extender sublayer

5. Architecture overview

This clause contains summaries of the information contained in later normative clauses and annexes as an aid to understanding this standard. This clause does not specify any normative behavior; other clauses and normative annexes have precedence when apparent conflicts arise.

5.1 Terminology

The following terms have special meaning within the context of this standard.

5.1.1 aggressive: An algorithm that tends to exhibit an underdamped transient response.

5.1.2 congested: The indication from a local station that a threshold has been crossed for the declaration of a state of congestion in attempting to add fairness eligible traffic.

5.1.3 context: The topology and status database used by a source station to transmit a frame.

5.1.4 copy: The transfer of an inbound frame from the ring to the MAC sublayer. The copying of a frame does not imply its removal from the ring.

5.1.5 delay¹³: The time required to transfer information from one point to another.

5.1.6 domain: A set of contiguous stations associated with a common property, such as an indicated congestion condition or transit paths affiliated with a specific frame transfer.

5.1.7 edge: A span on which data frames are not allowed to pass. This is a span on which a wrap is present in a wrapping ring, or a span that is unused for data transmission due to a protection condition in a steering ring.

5.1.8 hop: The distance associated with the transfer of data from one station to the next station in its path. This distance between adjacent stations is described as “one hop.”

5.1.9 insert: The placement of a frame on a ringlet by the source station.

5.1.10 latency: *Syn:* **delay**.

5.1.11 neighbor: A station that is exactly one link distant from a given station on the network.

5.1.12 network: A set of communicating stations and the media and equipment providing connectivity among the stations.

5.1.13 normalize: To adjust a local value to allow a global interpretation when the value is communicated to other stations on the ringlet.

5.1.14 opportunistic: The property of an algorithm that seeks the ability to utilize capacity that is available, or that becomes available.

5.1.15 path: The specific sequence of stations and links traversed by a frame transferred between two stations on the network.

5.1.16 police: The enforcement of traffic parameters.

¹³*Delay* and *latency* are synonyms for the purpose of this standard. *Delay* is the preferred term.