

# ISO/IEC/IEEE 8802-1AS:2021-11 (E)

## Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Part 1AS: Timing and synchronization for time-sensitive applications in bridged local area networks

---

### Contents

1. Overview.....	17
1.1 Scope.....	17
1.2 Purpose.....	17
2. Normative references.....	18
3. Definitions.....	20
4. Acronyms and abbreviations.....	23
5. Conformance.....	26
5.1 Requirements terminology.....	26
5.2 Protocol Implementation Conformance Statement (PICS).....	26
5.3 Time-aware system requirements.....	26
5.4 PTP Instance requirements and options.....	26
5.5 MAC-specific timing and synchronization methods for full-duplex IEEE 802.3 links.....	28
5.6 MAC-specific timing and synchronization methods for IEEE Std 802.11-2016.....	29
5.7 MAC-specific timing and synchronization methods for IEEE 802.3 EPON.....	29
5.8 MAC-specific timing and synchronization methods for coordinated shared network (CSN).....	29
6. Conventions.....	30
6.1 General.....	30
6.2 Service specification method and notation.....	30
6.3 Lexical form syntax.....	30
6.4 Data types and on-the-wire formats.....	30
7. Time-synchronization model for a packet network.....	35
7.1 General.....	35
7.2 Architecture of a time-aware network.....	35
7.3 Time synchronization.....	42
7.4 PTP Instance architecture.....	45
7.5 Differences between gPTP (IEEE Std 802.1AS) and PTP (IEEE Std 1588-2019).....	46
8. IEEE 802.1AS concepts and terminology.....	48
8.1 gPTP domain.....	48
8.2 Timescale.....	48
8.3 Link asymmetry.....	50
8.4 Messages.....	51
8.5 Ports.....	53
8.6 PTP Instance characterization.....	54
9. Application interfaces.....	59
9.1 Overview of the interfaces.....	59
9.2 ClockSourceTime interface.....	60
9.3 ClockTargetEventCapture interface.....	60
9.4 ClockTargetTriggerGenerate interface.....	61
9.5 ClockTargetClockGenerator interface.....	63

9.6	ClockTargetPhaseDiscontinuity interface .....	64
10.	Media-independent layer specification .....	65
10.1	Overview .....	65
10.2	Time-synchronization state machines .....	67
10.3	Best master clock selection, external port configuration, and announce interval setting state machines .....	98
10.4	State machines related to signaling gPTP capability .....	135
10.5	Message attributes .....	142
10.6	Message formats .....	143
10.7	Protocol timing characterization .....	156
11.	Media-dependent layer specification for full-duplex point-to-point links .....	160
11.1	Overview .....	160
11.2	State machines for MD entity specific to full-duplex point-to-point links .....	166
11.3	Message attributes .....	195
11.4	Message formats .....	197
11.5	Protocol timing characterization .....	205
11.6	Control of computation of neighborRateRatio .....	206
11.7	Control of computation of meanLinkDelay .....	207
12.	Media-dependent layer specification for IEEE 802.11 links .....	208
12.1	Overview .....	208
12.2	Messages .....	212
12.3	Determination of Timing Measurement and Fine Timing Measurement capability .....	214
12.4	Determination of asCapable .....	214
12.5	State machines .....	215
12.6	FTM parameters .....	227
12.7	Format of VendorSpecific information element .....	228
12.8	Synchronization message interval .....	229
13.	Media-dependent layer specification for interface to IEEE 802.3 Ethernet passive optical network link .....	230
13.1	Overview .....	230
13.2	Message attributes .....	234
13.3	Message format .....	234
13.4	Determination of asCapable .....	237
13.5	Layering for IEEE 802.3 EPON links .....	237
13.6	Service interface definitions .....	238
13.7	MD entity global variables .....	240
13.8	State machines .....	241
13.9	Message transmission intervals .....	244
14.	Timing and synchronization management .....	245
14.1	General .....	245
14.2	Default Parameter Data Set (defaultDS) .....	248
14.3	Current Parameter Data Set (currentDS) .....	251
14.4	Parent Parameter Data Set (parentDS) .....	253
14.5	Time Properties Parameter Data Set (timePropertiesDS) .....	255
14.6	Path Trace Parameter Data Set (pathTraceDS) .....	256
14.7	Acceptable Master Table Parameter Data Set (acceptableMasterTableDS) .....	257

14.8	Port Parameter Data Set (portDS).....	258
14.9	Description Port Parameter Data Set (descriptionPortDS).....	269
14.10	Port Parameter Statistics Data Set (portStatisticsDS).....	269
14.11	Acceptable Master Port Parameter Data Set (acceptableMasterPortDS).....	273
14.12	External Port Configuration Port Parameter Data Set (externalPortConfigurationPortDS).....	273
14.13	Asymmetry Measurement Mode Parameter Data Set (asymmetryMeasurementModeDS).....	274
14.14	Common Services Port Parameter Data Set (commonServicesPortDS).....	275
14.15	Common Mean Link Delay Service Default Parameter Data Set (cmlDsDefaultDS).....	275
14.16	Common Mean Link Delay Service Link Port Parameter Data Set (cmlDsLinkPortDS)....	276
14.17	Common Mean Link Delay Service Link Port Parameter Statistics Data Set (cmlDsLinkPortStatisticsDS).....	281
14.18	Common Mean Link Delay Service Asymmetry Measurement Mode Parameter Data Set (cmlDsAsymmetryMeasurementModeDS).....	283
15.	Managed object definitions.....	284
15.1	Internet Standard Management Framework.....	284
15.2	Structure of the MIB.....	284
15.3	Relationship to MIB in IEEE Std 802.1AS-2011.....	291
15.4	Security considerations.....	291
15.5	Textual conventions defined in this MIB.....	293
15.6	IEEE 802.1AS MIB module.....	293
16.	Media-dependent layer specification for CSN.....	368
16.1	Overview.....	368
16.2	Coordinated Shared Network characteristics.....	368
16.3	Layering for CSN links.....	369
16.4	Path delay measurement over a CSN backbone.....	370
16.5	Synchronization messages.....	373
16.6	Specific CSN requirements.....	377
16.7	Grandmaster PTP Instance capability.....	378
16.8	CSN clock and node performance requirements.....	378
Annex A	(normative) Protocol Implementation Conformance Statement (PICS) proforma.....	379
A.1	Introduction.....	379
A.2	Abbreviations and special symbols.....	379
A.3	Instructions for completing the PICS proforma.....	380
A.4	PICS proforma for IEEE Std 802.1AS-2020.....	382
A.5	Major capabilities.....	383
A.6	Media access control methods.....	384
A.7	Minimal time-aware system.....	384
A.8	Signaling.....	386
A.9	Best master clock.....	387
A.11	Media-independent master.....	389
A.10	Grandmaster-capable PTP Instance.....	389
A.12	Media-independent performance requirements.....	390
A.13	Media-dependent, full-duplex point-to-point link.....	391
A.15	Media-dependent IEEE 802.3 EPON link.....	394
A.14	Media-dependent IEEE 802.11 link.....	394
A.16	Media-dependent CSN link.....	395
A.17	Media-dependent MoCA link.....	395

A.19	Remote management.....	396
A.20	Application interfaces .....	396
A.21	External port configuration.....	396
A.18	Media-dependent ITU-T G.hn link .....	396
Annex B	(normative) Performance requirements .....	397
B.1	LocalClock requirements .....	397
B.2	PTP Instance requirements .....	402
B.3	End-to-end time-synchronization performance .....	403
B.4	End-to-end jitter and wander performance .....	403
Annex C	(informative) Timescales and epochs .....	405
C.1	Overview .....	405
C.2	TAI and UTC .....	405
C.3	NTP and GPS.....	407
C.4	Timescale conversions.....	407
C.5	Time zones and GMT .....	408
Annex D	Reserved for future use .....	409
Annex E	Reserved for future use .....	410
Annex F	(informative) PTP profile included in this standard .....	411
F.1	General.....	411
F.2	Identification.....	411
F.3	PTP attribute values .....	412
F.4	PTP options.....	412
F.5	LocalClock and PTP Instance performance requirements.....	413
Annex G	(informative) The asymmetry compensation measurement procedure based on line-swapping	414
G.1	Introduction.....	414
G.2	Pre-conditions for measurement .....	414
G.3	Measurement procedure.....	414
Annex H	(informative) Bibliography .....	417

## List of figures

Figure 7-1—Time-aware network example.....	36
Figure 7-2—Time-aware network of Figure 7-1 after an access network link failure .....	37
Figure 7-3—Time-aware network example for multiple gPTP domains .....	38
Figure 7-4—Time-aware network example for synchronization path redundancy, with one clock source providing time to two domains .....	40
Figure 7-5—Time-aware network example for GM redundancy with one primary GM and one hot-standby GM, which are separated in two gPTP domains .....	41
Figure 7-6—Time-aware network example for GM+synchronziation path redundancy, with one primary and one hot-standby GM. Each GM establishes two sync trees, resulting in a total of four Sync trees that are separated in four gPTP domains .....	42
Figure 7-7—Conceptual medium delay measurement .....	43
Figure 7-8—PTP Instance model .....	45
Figure 8-1—Propagation asymmetry.....	50
Figure 8-2—Definition of message timestamp point, reference plane, timestamp measurement plane, and latency constants .....	52
Figure 9-1—Application interfaces .....	59
Figure 10-1—Model for media-independent layer of PTP Instance .....	66
Figure 10-2—Time-synchronization state machines—overview and interrelationships.....	68
Figure 10-3—SiteSyncSync state machine.....	84
Figure 10-4—PortSyncSyncReceive state machine .....	86
Figure 10-5—ClockMasterSyncSend state machine .....	88
Figure 10-6—ClockMasterSyncOffset state machine .....	90
Figure 10-7—ClockMasterSyncReceive state machine .....	92
Figure 10-8—PortSyncSyncSend state machine .....	95
Figure 10-9—ClockSlaveSync state machine .....	97
Figure 10-10—Example master/slave hierarchy of PTP Instances .....	99
Figure 10-11—Best master clock selection state machines—overview and interrelationships .....	105
Figure 10-12—External port configuration state machines—overview and interrelationships .....	106
Figure 10-13—PortAnnounceReceive state machine .....	116
Figure 10-14—PortAnnounceInformation state machine.....	118
Figure 10-15—PortStateSelection state machine .....	121
Figure 10-16—PortAnnounceInformationExt state machine .....	123
Figure 10-17—PortStateSettingExt state machine .....	126
Figure 10-18—PortAnnounceTransmit state machine .....	128
Figure 10-19—AnnounceIntervalSetting state machine.....	131
Figure 10-20—SyncIntervalSetting state machine .....	134
Figure 10-21—GptpCapableTransmit state machine .....	136
Figure 10-22—GptpCapableReceive state machine.....	138
Figure 10-23—GptpCapableIntervalSetting state machine.....	141
Figure 11-1—Propagation delay measurement using peer-to-peer delay mechanism .....	161
Figure 11-2—Transport of time-synchronization information.....	163
Figure 11-3—Model for a PTP Instance of a time-aware system with full-duplex point-to-point links ...	166
Figure 11-4—Detail of MD entity time-synchronization state machines for full-duplex point-to-point links .....	167
Figure 11-5—Peer-to-peer delay mechanism state machines—overview and interrelationships .....	167
Figure 11-6—MDSyncReceiveSM state machine.....	175
Figure 11-7—MDSyncSendSM state machine.....	179
Figure 11-8—OneStepTxOperSetting state machine .....	181
Figure 11-9—MDPdelayReq state machine .....	188
Figure 11-10—MDPdelayResp state machine .....	191
Figure 11-11—LinkDelayIntervalSetting state machine.....	194

Figure 12-1—Timing measurement procedure for IEEE 802.11 links .....	209
Figure 12-2—Fine Timing Measurement procedure for IEEE 802.11 links .....	209
Figure 12-3—Illustration of Fine Timing Measurement burst .....	211
Figure 12-4—Media-dependent and lower entities in stations with IEEE 802.11 links .....	213
Figure 12-5—Master state machine A: (a) For TM, receives information from the PortSync entity and sends to slave, and (b) for FTM, receives and stores information from the PortSync entity .....	216
Figure 12-6—Master state machine B: (a) For TM, not invoked and (b) for FTM, receives initial FTM request from slave and sends information received from upstream to slave in successive FTM frames...	217
Figure 12-7—Slave state machine .....	223
Figure 12-8—Format of VendorSpecific information element when Type = 0 .....	228
Figure 13-1—IEEE 802.3 EPON time-synchronization interfaces .....	233
Figure 13-2—IEEE 802.3 EPON interface model.....	238
Figure 13-3—State machine for IEEE 802.3 EPON requester.....	242
Figure 13-4—State machine for IEEE 802.3 EPON responder.....	244
Figure 16-1—Example of CSN backbone in a TSN LAN .....	368
Figure 16-2—Media-dependent and lower entities in CSN nodes .....	369
Figure 16-3—Path types over CSN as IEEE 802.1AS backbone.....	370
Figure 16-4—Propagation delay and residence time over a CSN backbone.....	370
Figure 16-5—CSN node-to-node path delay measurement.....	371
Figure 16-6—IEEE 802.1AS Sync message propagation over the CSN backbone .....	373
Figure B-1—Wander generation (TDEV) requirement for LocalClock entity .....	399
Figure B-2—ADEV limit corresponding to wander generation requirement of Figure B-1.....	400
Figure B-3—PTPDEV limit corresponding to wander generation requirement of Figure B-1.....	401
Figure B-4—MTIE masks met for maximum endpoint filter bandwidths of Table B-4.....	404
Figure G-1—Asymmetry compensation measurement procedure .....	415

## List of tables

Table 6-1—Primitive data types .....	31
Table 8-1—Default values for priority1, for the respective media.....	55
Table 8-2—TimeSource enumeration .....	57
Table 10-1—Summary of scope of global variables used by time synchronization state machines (see 10.2.4 and 10.2.5).....	76
Table 10-2—PTP Port state definitions .....	98
Table 10-3—Summary of scope of global variables used by best master clock selection, external port configuration, and announce interval setting state machines (see 10.3.9 and 10.3.10).....	107
Table 10-4—Destination address for Announce and Signaling messages .....	142
Table 10-5—EtherType for Announce and Signaling messages.....	142
Table 10-6—Propagate TLVs of IEEE Std 1588-2019 .....	144
Table 10-7—PTP message header.....	144
Table 10-8—Values for messageType field .....	145
Table 10-9—Values of flag bits.....	146
Table 10-10—messageTypeSpecific semantics .....	147
Table 10-11—Announce message fields .....	148
Table 10-12—Path trace TLV .....	149
Table 10-13—Signaling message fields .....	150
Table 10-14—Message interval request TLV .....	151
Table 10-15—Interpretation of special values of logLinkDelayInterval.....	152
Table 10-16—Interpretation of special values of logTimeSyncInterval .....	152
Table 10-17—Interpretation of special values of logAnnounceInterval .....	153
Table 10-18—Definitions of bits of flags field of message interval request TLV .....	153
Table 10-19—gPTP-capable TLV.....	154
Table 10-20—gPTP-capable message interval request TLV.....	155
Table 10-21—Interpretation of special values of logGtpCapableMessageInterval.....	156
Table 11-1—Value of meanLinkDelayThresh for various links .....	169
Table 11-2—Summary of scope of global variables used by time synchronization state machines (see 10.2.4 and 10.2.5).....	171
Table 11-3—Destination address for Sync, Follow_Up, Pdelay_Req, Pdelay_Resp, and Pdelay_Resp_Follow_Up messages .....	196
Table 11-4—EtherType for Sync, Follow_Up, Pdelay_Req, Pdelay_Resp, and Pdelay_Resp_Follow_Up messages .....	196
Table 11-5—Values for messageType field .....	198
Table 11-6—Value of correctionField.....	199
Table 11-7—References for sequenceId value exceptions.....	199
Table 11-8—Sync message fields if twoStep flag is TRUE.....	200
Table 11-9—Sync message fields if twoStep flag is FALSE.....	200
Table 11-10—Follow_Up message fields .....	201
Table 11-11—Follow_Up information TLV .....	202
Table 11-12—Pdelay_Req message fields .....	203
Table 11-13—Pdelay_Resp message fields.....	204
Table 11-14—Pdelay_Resp_Follow_Up message fields .....	204
Table 12-1—Values of bits of tmFtmSupport .....	214
Table 12-2—FTM parameters relevant to time-synchronization transport .....	227
Table 12-3—Values of Burst Duration and Min Delta FTM, for each value of currentLogSyncInterval .	228
Table 12-4—Values of the Type field in the VendorSpecific information element.....	228
Table 13-1—TIMESYNC message fields .....	235
Table 14-1—defaultDS table .....	251
Table 14-2—currentDS table.....	253
Table 14-3—parentDS table .....	255

Table 14-4—timePropertiesDS table.....	256
Table 14-5—pathTraceDS table .....	257
Table 14-6—acceptableMasterTableDS table .....	258
Table 14-7—portState enumeration.....	258
Table 14-8—delayMechanism enumeration.....	259
Table 14-9—Description of pdelayTruncatedTimestampsArray .....	266
Table 14-10—portDS table.....	267
Table 14-11—descriptionPortDS table.....	269
Table 14-12—portStatisticsDS table .....	272
Table 14-13—acceptableMasterPortDS table .....	273
Table 14-14—externalPortConfigurationPortDS table .....	274
Table 14-15—asymmetryMeasurementModeDS table .....	274
Table 14-16—commonServicesPortDS table.....	275
Table 14-17—cmlDsDefaultDS table.....	276
Table 14-18—cmlDsLinkPortDS table .....	280
Table 14-19—cmlDsLinkPortStatisticsDS table.....	282
Table 14-20—cmlDsAsymmetryMeasurementModeDS table.....	283
Table 15-1—IEEE8021-AS-V2 MIB structure and object cross reference.....	285
Table 16-1—CSN TLV .....	375
Table 16-2—Definitions and option selections per link technology .....	377
Table B-1—Wander generation TDEV requirement for LocalClock entity .....	399
Table B-2—ADEV limit corresponding to wander generation requirement of Table B-1 .....	400
Table B-3—PTPDEV limit corresponding to wander generation requirement of Table B-1 .....	401
Table B-4—Maximum endpoint filter bandwidths needed to meet respective MTIE masks and peak-to-peak jitter limits .....	403
Table B-5—Breakpoints for Mask 1 .....	404
Table B-6—Breakpoints for Mask 2 .....	404
Table C-1—Timescale parameters .....	405
Table C-2—Timescale conversions.....	408