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FOREWORD

<<Contributor's notes:

This document has been contributed to the IEC/IEEE 60802 Joint Project via the 1st Task Group ballot on D1.0.

The only intention with this document is to outline some potential slight restructuring of the Draft for consideration for the group.

The intention behind the proposal is to improve clarity and readability of the Draft (improve the “flow” of the Draft.)

No rewrite is suggested by this contribution.

The contributor has submitted separate ballot comments with respect to the content of the Draft.

This contribution only focuses on the structure. The content aimed to be kept the same as D1.0, with some illustrative suggested new text in some of the suggested new clauses. However, restructuring and reformatting may provide a different look. Furthermore, some introductory text is suggested at the beginning of some of the clauses to aid the flow of reading.

In order to make it clearer that this is just an individual contribution not an IEC/IEEE 60802 Draft, the FOREWORD has been replaced with this explanation and the INTRODUCTION has been removed.

Proper cross-references were used in the contribution; however, the final outcome is not under the control of the contributor.

This commenter suggests two restructuring steps. This version of the contribution only includes Step 1.

Step 1: Structure

Different kind of requirements could be distinguished clearer. There are conformance requirements. There are requirements coming from Industrial Automation being the target, e.g., from the characteristics of control loops etc. All kinds of requirements are in Clause 6 in D1.0. It would be good to have the conformance and other kind of requirements in separate Clauses.

The Conformance Clause will be not part of the “reading flow” of the document anyways, so it would be good to have it before or after the descriptive clauses. As the Conformance Clause can give orientation to the reader, this commenter suggests having the Conformance Clause right after the terms and definitions, i.e., as Clause 4.

The “Overview of TSN for Industrial Automation” Clause could be Clause 5, i.e., follow Clause 4 Conformance.

The requirements coming from the nature of Industrial Automation, could be part of Clause 5 Overview of TSN for Industrial Automation, because they are closely related to what is Industrial Automation. With that the title of Clause 5 could be “Industrial Automation” with subclauses 5.1 Overview and 5.2 Requirements and an introductory text before 5.1. Thus, Clause 5 would give input to the rest of the document, e.g., to verbal description of industrial profile(s).

If textual description will be provided for the Industrial Automation profile, then it is suggested to be Clause 6.

>>



1
2
3

INTRODUCTION

Time-sensitive networking profile for industrial automation

1 Scope

This standard defines time-sensitive networking profiles for industrial automation. The profiles select features, options, configurations, defaults, protocols, and procedures of bridges, end stations, and LANs to build industrial automation networks.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Editor Note: The list of normative references will be updated before CDV circulation.

IEEE P802.1AS-Rev/D7.4, June 12, 2017– *IEEE Draft standard for Local and metropolitan area networks – Timing and Synchronization for Time-Sensitive Applications*

IEEE Std 802.1AE™-2006, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Security*

IEEE Std 802.1AEbn™-2011, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Security Amendment 1: Galois Counter Mode—Advanced Encryption Standard—256 (GCM-AES-256) Cipher Suite*

IEEE Std 802.1AEbw™-2013, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Security Amendment 2: Extended Packet Numbering*

IEEE P802.1AEcg/D1.5, October 25, 2016, *IEEE Draft Standard for Local and metropolitan area networks—Media Access Control (MAC) Security Amendment 3: Ethernet Data Encryption devices*

IEEE Std 802.1AR™-2009, *IEEE Standard for Local and metropolitan area networks – Secure Device Identity*

IEEE Std 802.1Q™-2014, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks*, available at <http://www.ieee.org>

IEEE P802.1Qcc/ D1.1, September 1, 2016, *IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks Amendment: Stream Reservation Protocol (SRP) Enhancements and Performance Improvements*

IEEE 802.1Qch™-2017, *IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks—Amendment: Cyclic Queuing and Forwarding*

IEEE 802.1Qci™-2017, *IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks—Amendment: Per Stream Filtering and Policing*

IEEE 802.1CB™-2017, *IEEE Standard for Local and metropolitan area networks—Frame Replication and Elimination for Reliability*

IEEE P802.1CS/ D0.0, *IEEE Standard for Local and metropolitan area networks—LRP (Registration)*

IEEE P802.1Qcj/D0.1 March 7, 2016, *IEEE Standard for Local and Metropolitan Area Networks— Bridges and Bridged Networks—Automatic Attachment to Provider Backbone Bridging (PBB) services*

47 IEEE P802.1Qcp/ D0.7 December 12, 2016, *IEEE Standard for Local and Metropolitan Area*
48 *Networks—Bridges and Bridged Networks—Amendment: YANG Data Model*

49 IEEE P 802.1Qcr/D0.2, October 20, 2017, *IEEE Standard for Local and Metropolitan Area*
50 *Networks—Bridges and Bridged Networks—Amendment: Asynchronous Traffic Shaping*

51 IEEE Std 802.1X-2010, *IEEE Standard for Local and Metropolitan Area Networks—Port-based*
52 *Network Access Control*, available at <<http://www.ieee.org>>

53 IEEE 802.3-2015, *IEEE Standard for Ethernet*, available at <<http://www.ieee.org>>

54 IEEE Std 802.3bp™-2016, *IEEE Standard for Ethernet - Amendment 4: Physical Layer*
55 *Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair*
56 *Copper Cable*

57 IEEE Std 802.3br™-2016, *IEEE Standard for Ethernet - Amendment 5: Specification and*
58 *Management Parameters for Interspersing Express Traffic*

59 IEEE Std 802.3bu™-2016, *IEEE Standard for Ethernet – Amendment #: Physical Layer and*
60 *Management Parameters for Power over Data Lines (PoDL) of Single Balanced Twisted-Pair*
61 *Ethernet*

62 IEEE P802.3bv™/D3.3, 12th December 2016^{Error! Bookmark not defined.}, *IEEE Standard for Ethernet*
63 *– Amendment 9: Physical Layer Specifications and Management Parameters for 1000 Mb/s*
64 *Operation Over Plastic Optical Fiber*

65 IEEE P802.3cg, *IEEE Standard for Ethernet – Amendment: Physical Layer Specifications and*
66 *Management Parameters for 10 Mb/s Operation over Single Balanced Twisted-pair Cabling and*
67 *Associated Power Delivery*

68

69 **3 Terms, definitions, symbols and abbreviated terms**

70 For the purposes of this document, the terms and definitions given in IEC 61784-2, IEEE 802,
71 IEEE 802.3, IEEE 802.1Q and IEEE 802.1AS and the following apply.

- 72 • ISO Online browsing platform: available at <https://www.iso.org/obp>
- 73 • IEC Electropedia: available at <http://www.electropedia.org/>

74 **3.1 TSN-IA defined Terms**

75

76 **3.1.1**

77 **TSN Domain**

78 quantity of commonly managed industrial automation devices

79 Note 1 to entry: It is an administrative decision to group these devices.

80

81

82 **3.2 List of terms and definitions given in IEC 61784-2, IEEE 802, IEEE 802.3,** 83 **IEEE 802.1Q and IEEE 802.1AS**

84 For ease of understanding the most important terms used within this profile document are listed
85 but not repeated in Table 1.

86

Table 1 – List of terms

Term	Source
Bridge	IEEE Std 802.1Q™-2018

Bridge Port	IEEE Std 802.1Q™-2018
Bridged Network	IEEE Std 802.1Q™-2018
end station	IEEE Std 802
Ethernet	IEEE Std 802.1Q™-2018
Frame	IEEE Std 802.1Q™-2018
Frame relay	IEEE Std 802.1Q™-2018
latency	IEEE Std 802.1Q™-2018
Listener	IEEE Std 802.1Q™-2018
Port	IEEE Std 802.1Q™-2018
preemption	IEEE Std 802.1Q™-2018
station	IEEE Std 802
Stream	IEEE Std 802.1Q™-2018
Talker	IEEE Std 802.1Q™-2018
time-sensitive stream	IEEE Std 802.1Q™-2018
traffic class	IEEE Std 802.1Q™-2018

87

88 **3.3 Abbreviated terms and acronyms**

89 **Editor’s Note: has to be updated before CDV stage!**

IA Industrial automation

90 **3.4 Conventions**

91 **3.4.1 Conventions for (sub)clause selections of referenced documents**

92 (Sub)clause selections of referenced documents are done in tables, as shown in Table 2 and
 93 Table 3. The selected base specifications are indicated just before the selection table(s) or in
 94 the table title. Selections are done at the highest (sub)clause level possible to define the profile
 95 selection unambiguously.

96 **Table 2 – Layout of profile (sub)clause selection tables**

Clause	Header	Presence	Constraints

97

98

Table 3 – Contents of (sub)clause selection tables

Column	Text	Meaning
Clause	<#>	(Sub)clause number of the base specifications
	Next clauses	any following clauses up to the last clause of the base specification
	Next Annexes	any following annexes up to the last annex of the base specification
Header	<text>	(Sub)clause title of the base specifications
Presence	NO	This (sub)clause is not included in the profile
	YES	This (sub)clause is fully (100 %) included in the profile in this case no further detail is given
	—	Presence is defined in the following (sub)clauses
	Partial	Parts of this (sub)clause are included in the profile
	Optional	This (sub)clause may be additionally included in the profile
Constraints	See <#>	Constraints/remarks are defined in the given (sub)clause, table or figure of this profile document
	—	No constraints other than given in the reference document (sub)clause, or not applicable
	<text>	The text defines the constraint directly; for longer text table footnotes or table notes may be used

99

100 If sequences of (sub)clauses match or do not match the profile, then the numbers are
101 concatenated.

102 EXAMPLE Concatenated (sub)clauses

1 – 6	—	YES	—
7 – 11	—	NO	—

103

104 Conventions for different cases in selection tables, which apply for multiple or different device
105 types (end-station, bridge):

- 106 1. Presence column value YES and NO Constraints given: This (sub)clause is fully (100 %)
107 included in the profile for all device types
- 108 2. Presence column value YES and some Constraints given: the constraints can limit the
109 applicability to a device type
- 110 3. Presence column value PARTIAL and general Constraints without device type
111 constraints given: the constraints can limit the applicability to all device types
- 112 4. Presence column value PARTIAL and general Constraints with device type constraints
113 given: the constraints limit the applicability to a device types
- 114 5. Presence column value NO and no Constraints given: This (sub)clause is not included
115 in the profile for all device types
- 116 6. Subclauses, which are dedicated to a specific device type, do not need to repeat the
117 device type applicability in the Constraints column.

118 Table 4 shows an example of a selection table that apply for multiple device types (end-station,
119 bridge). The Clause numbers used in Table 4 corresponds to the list numbers above.

120

Table 4 – Example of a selection table that apply for multiple device types

Clause	Header	Presence	Constraints
1	Xyz	YES	—
2	Xyz	YES	Applicable to device type end-station only
3	Media Access Control (MAC) frame and packet specifications	PARTIAL	The option xyz does not apply
4	Xyz	PARTIAL	The option xyz does not apply Applicable to device type end-station only
5	Xyz	NO	—
6	End-station behavior	YES	—

121

122 3.4.2 Convention for Capitalizations

123 Capitalized terms are either based on the rules given in the ISO/IEC Directives Part 2 or
124 emphasize that these terms have a specific meaning throughout this document.

125 The following capitalized terms are used:

- 126 – Bridge
- 127 – Ethernet
- 128 – Internet
- 129 – Universal Time
- 130 – Working Clock

131

132 Parameter names are capitalized for example

- 133 – MinimumFrameMemory
- 134 – NetworkCycleTime
- 135 – NetworkCycle
- 136 – Phase
- 137 – ReductionRatio
- 138 – Sequence.

139

140 3.4.3 Unit conventions

141 This document uses

- 142 – Tbps for Tbit/s
- 143 – Gbps for Gbit/s and
- 144 – Mbps for Mbit/s.

145 This form is used by IEEE 802.3 and as this document is a profile to IEEE 802, it is better
146 readable and consistent.

147 4 Conformance

148 A claim of conformance to this standard is a claim that the behavior of an implementation of a
149 bridge (X.X, X.X) or of an end station (X.X, X.X) meets the mandatory requirements of this
150 standard and may support options identified in this standard.

151 **4.1 Requirements Terminology**

152
153 The Profile Conformance Statement (PCS) proformas (see Annex A) reflect the occurrences of
154 the words “shall,” “may,” and “should” within this document.

155
156 **4.2 Profile Conformance Statement (PCS)**

157 The supplier of an implementation that is claimed to conform to this standard shall provide the
158 information necessary to identify both the supplier and the implementation, and shall complete
159 a copy of the PCS proforma provided in Annex A.

160 **4.3 Required Functions for an Industrial Network**

161 **4.3.1 PHY and MAC selection**

162 **4.3.1.1 General**

163 The following requirements and features according to IEEE 802.3 shall be supported:

164 a) Select one of the PHY with data rates from 10 Mbps to 1 Tbps with

- 165 o Full duplex, and
- 166 o Synchronization according IEEE 802.1AS supported.

167 Table 5 specifies the elements of IEEE 802.3-2018 applicable to this profile. At least one
168 PHY shall be selected out of the list of possible PHYs.

169 b) The maximum frame size according IEEE 802.3-2015, 3.2.7, including envelope frame, shall
170 be supported.

171 *Editor’s Note: TBD: check max frame size in 802.1Q*

172 c) IEEE 802.3br™-2016 (preemption) up to 1 Gb/s; beyond optional.

173 NOTE May be indicated by Annex A parameter.

174 d) The selected medium shall be described in the IEEE 802.3 defined managed object.

175 **4.3.1.2 IEEE 802.3-2015 Selections**

176 Table 5 specifies the (sub) clause selection of IEEE 802.3-2015.

177 **Table 5 – PHY and MAC selection within IEEE 802.3-2015**

Clause	Header	Presence	Constraints
2	Media Access Control (MAC) service specification	YES	–
3	Media Access Control (MAC) frame and packet specifications	YES	–
4	Media Access Control	YES	–
5	Layer Management	YES	–
6	Physical Signaling (PLS) service specifications	YES	–
7	Physical Signaling (PLS) and Attachment Unit Interface (AUI) specifications	YES	–
8 - 77	--	Partial	Applies only if 4.3.1.1 fulfilled.
Annex 57A - 76A	–	Partial	Applies only if 4.3.1.14.3.1.1 fulfilled.
78	Energy-Efficient Ethernet (EEE)	NO	
79	IEEE 802.3 Organizationally Specific Link Layer Discovery Protocol (LLDP) type, length, and value (TLV) information elements	YES	Relevant for IEEE 802.3br
80 - 89	–	Partial	Applies only if 4.3.1.1 fulfilled.
90	Ethernet support for time synchronization protocols	YES	Relevant for IEEE 802.3br

Clause	Header	Presence	Constraints
91 - 95	–	Partial	Applies only if 4.3.1.1 fulfilled.
Annex 83A – 93C	–	Partial	Applies only if 4.3.1.1 fulfilled.

178

179

Table 6 – CP 802PHY/2 PHY selection and the MAC speeds of Amendments

Amendment	Title	Presence	Constraints
IEEE 802.3bw™-2015	IEEE Standard for Ethernet - Amendment 1: Physical Layer Specifications and Management Parameters for 100 Mb/s Operation over a Single Balanced Twisted Pair Cable (100BASE-T1)	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE 802.3by™-2016	IEEE Standard for Ethernet - Amendment 2: Media Access Control Parameters, Physical Layers, and Management Parameters for 25 Gb/s Operation	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE 802.3bq™-2016	IEEE Standard for Ethernet - Amendment 3: Physical Layers and Management Parameters for 25 Gb/s and 40 Gb/s Operation, Types 25GBASE-T and 40GBASE-T	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE 802.3bp™-2016	IEEE Standard for Ethernet - Amendment 4: Physical Layer Specifications and Management Parameters for 1 Gb/s Operation over a Single Twisted-Pair Copper Cable	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE 802.3br™-2016	IEEE Standard for Ethernet - Amendment 5: Specification and Management Parameters for Interspersing Express Traffic	YES	Yes to all Options in 79.5 up to 1 Gb/s; beyond optional.
IEEE 802.3bz™-2016	IEEE Standard for Ethernet - Amendment 7: Media Access Control Parameters, Physical Layers, and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation, Types 2.5GBASE-T and 5GBASE-T	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3bs™ /D2.2, 28th November 2016	IEEE Standard for Ethernet - Amendment #: Media Access Control Parameters, Physical Layers and Management Parameters for 200 Gb/s and 400 Gb/s Operation	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3bt™/D 2.2, 28 November 2016	IEEE Standard for Ethernet - Amendment #: Physical Layer and Management Parameters for DTE Power via MDI over 4-Pair	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3bu™/D3.3, 11 October 2016	IEEE Standard for Ethernet – Amendment #: Physical Layer and Management Parameters for Power over Data Lines (PoDL) of Single Balanced Twisted-Pair Ethernet	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3bv™/D3.3, 12th December 2016	IEEE Standard for Ethernet – Amendment 9: Physical Layer Specifications and Management Parameters for 1000 Mb/s Operation Over Plastic Optical Fiber	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3ca™/D0.0, No Draft	IEEE Standard for Ethernet – Amendment #: Physical Layer Specifications and Management Parameters for 25 Gb/s, 50 Gb/s, and 100 Gb/s Passive Optical Networks	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3cb-20xx™/D2.1, 15th December 2016	IEEE Standard for Ethernet – Amendment #: Physical Layer Specifications and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation over Backplane	Partial	Applies only if 4.3.1.1 fulfilled.

Amendment	Title	Presence	Constraints
IEEE P802.3cc™/D2.0, 27th November 2016	IEEE Standard for Ethernet – Amendment #: Physical Layer and Management Parameters for Serial 25 Gb/s Ethernet Operation Over Single-Mode Fiber	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3cd™/D1.1, 2nd December 2016	IEEE Standard for Ethernet – Amendment #: Media Access Control Parameters for 50 Gb/s and Physical Layers and Management Parameters for 50 Gb/s, 100 Gb/s, and 200 Gb/s Operation	Partial	Applies only if 4.3.1.1 fulfilled.
IEEE P802.3cg™/Draft	IEEE Standard for Ethernet – Amendment #: 10 Mb/s Single Twisted Pair Ethernet	Partial	Applies only if 4.3.1.1 fulfilled.

180

181 **4.3.2 IEEE 802.1 selection**

182 **4.3.2.1 General**

183 **4.3.2.1.1 General required Bridge features**

184 The following requirements and features according to IEEE 802.1 shall be supported:

- 185 a) Support the capability of 2 000 octets maximum size MAC Protocol Data Unit (PDU) on each
- 186 port.
- 187 b) Support the capability to disable MAC control PAUSE if it is implemented and support the
- 188 capability to disable Priority-based flow control if it is implemented.
- 189 c) Support the capability to disable support of Energy Efficient Ethernet.
- 190 d) Support the strict priority algorithm for transmission selection (8.6.8.1 in IEEE Std 802.1Q-
- 191 2014) on each port for each traffic class.
- 192 e) Support a minimum of 8 Traffic Classes/Queues on every port.
- 193 f) Support flow metering according to IEEE 802.1Q, 8.6.5.
- 194 g) Support priority regeneration according to IEEE 802.1Q, 6.9.4.
- 195 h) Support of preemption according to IEEE 802.1Q-2018, 5.26, 6.7.2, 12.30, 17.2.23, 17.3.24,
- 196 17.4.24, 17.7.23, and Annex R.
- 197 i) Time limits for bridge delay and delay variation according to 4.3.3.
- 198 j) Required number of DA-MAC address entries used together with five VLANs (Default, High,
- 199 High Redundant, Low and Low Redundant) according to ...

200 Editor's note: insert reference to appropriate section once "FDB and resource

201 requirements" discussion is concluded.

202 **4.3.2.2 Bridge selections**

203 **Selection of IEEE 802.1Q-2018 and the related Amendments**

204 Selections of IEEE 802.1Q™-2018 are specified in Table 7. The current amendments to IEEE

205 802.1Q are selected inTable 8.

206

Table 7 – Selection of IEEE 802.1Q-2018

Clause	Header	Presence	Constraints
5.3	Protocol Implementation Conformance Statement (PICS)	YES	–
5.4	VLAN Bridge component requirements	YES	–
5.4.1	VLAN Bridge component options	YES	Optional
5.4.1.1	Multiple Spanning Tree (MST) operation	YES	–
5.4.1.2	Port-and-Protocol-based VLAN classification	NO	–

Clause	Header	Presence	Constraints
5.4.1.3	Multiple MAC Registration Protocol (MMRP) operation	YES	Optional
5.4.1.4	Connectivity Fault Management (CFM)	NO	–
5.4.1.5	Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS)— requirements	YES	Optional
5.4.1.6	ETS Bridge requirements	NO	–
5.4.1.7	DCBX Bridge requirements	NO	–
5.4.1.8	Per-stream filtering and policing (PSFP) requirements	YES	Optional
5.4.1.9	Cyclic queuing and forwarding (CQF) requirements	YES	Optional
5.4.2	Multiple VLAN Registration Protocol (MVRP) requirements	YES	Optional
5.4.3	VLAN Bridge requirements for congestion notification	NO	–
5.4.4	Multiple Stream Registration Protocol (MSRP) requirements	YES	Optional
5.4.5	Shortest Path Bridging (SPB) operation	NO	–
5.4.6	Path Control and Reservation (PCR)	NO	–
5.5	C-VLAN component conformance	YES	–
5.5.1	C-VLAN component options	YES	Optional
5.6	S-VLAN component conformance	NO	–
5.7	I-component conformance	NO	–
5.8	B-component conformance	NO	–
5.9	C-VLAN Bridge conformance	YES	–
5.10	Provider Bridge conformance	NO	–
5.11	System requirements for Priority-based Flow Control (PFC)	NO	–
5.12	Backbone Edge Bridge (BEB) conformance	NO	–
5.13	MAC Bridge component requirements	YES	–
5.13.1	MAC Bridge component options	YES	Optional
5.14	MAC Bridge conformance	YES	–
5.14.1	MAC Bridge options	YES	Optional
5.15	TPMR component conformance	NO	–
5.16	TPMR conformance	NO	–
5.17	T-component conformance	NO	–
5.18	End station requirements for MMRP, MVRP, and MSRP	YES	Optional
5.19	VLAN-aware end station requirements for CFM	NO	–
5.20	End station requirements—FQTSS	YES	Optional
5.21	End station requirements for congestion notification	NO	–
5.22	MAC-specific bridging methods	YES	–
5.23	EVB Bridge requirements	NO	–
5.24	EVB station requirements	NO	–
5.25	End station requirements—enhancements for scheduled traffic	YES	Optional
5.26	End station requirements—enhancements for frame preemption	YES	Optional

Clause	Header	Presence	Constraints
5.27	End-station requirements—PSFP	YES	Optional
5.28	End station requirements—Cyclic queuing and forwarding	YES	Optional

207

208 **4.3.2.3 Applicable amendments to IEEE 802.1Q™-2018**

209

Table 8 – Bridge selections of current amendments to IEEE 802.1Q™-2018

Amendment	Title	Presence	Constraints
IEEE P802.1Qcc™-2018	IEEE Standard for Local and Metropolitan Area Networks – Bridges and Bridged Networks Amendment: Stream Reservation Protocol (SRP) Enhancements and Performance Improvements	YES	Optional
IEEE P802.1Qcj/D 0.1 March 7, 2016	IEEE Standard for Local and Metropolitan Area Networks— Bridges and Bridged Networks— Automatic Attachment to Provider Backbone Bridging (PBB) services	NO	–
IEEE P802.1Qcp/D0.7 December 12, 2016	IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks— Amendment: YANG Data Model	YES	Optional if SNMP and MIBs are implemented.
IEEE P 802.1Qcr/D0.0	IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks— Amendment: Asynchronous Traffic Shaping	YES	Optional
IEEE P 802.1Qdd/D0.0	IEEE Standard for Local and Metropolitan Area Networks—Bridges and Bridged Networks— Amendment: RAP	YES	Optional

210

211 **4.3.2.4 Clock synchronization selection**

212 The IEEE 802.1AS™-2019 shall apply according to Table 9.

213 **4.3.2.5 IEEE 802.1AS-2019 Selections**

214

215 **Table 9 – Selection of IEEE 802.1AS-2019**

Clause	Header	Presence	Constraints
5.2	Protocol Implementation Conformance Statement (PICS)	YES	–
5.3	Time-aware system requirements	YES	–
5.4	PTP Instance requirements	YES	–
5.4.1	Time-aware system options	YES	Optional
5.4.2	PTP Relay Instance requirements	YES	–
5.5	MAC-specific timing and synchronization methods for IEEE 802.3 full-duplex links	YES	–
5.6	MAC-specific timing and synchronization methods for IEEE Std 802.11	YES	Optional
5.7	MAC-specific timing and synchronization methods for IEEE 802.3 EPON	NO	–
5.8	MAC-specific timing and synchronization methods for coordinated shared network (CSN)	NO	–

216

217

218

Editor’s Note: The Time-aware system options of 5.4.1 should be examined carefully to determine if any of those options should be mandatory for the purposes of this profile. A contribution is welcome.

219 **4.3.3 Security selection**

220 Media Access Control (MAC) Security according to IEEE 802.1AE can be used as an option.

221 Table 10 specifies the optional MAC-Security selection.

222 **Table 10 – MAC-Security selection**

Amendment	Title	Presence	Constraints
IEEE 802.1AE™-2006	IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Security	YES	Optional
IEEE 802.1AEbn™-2011	IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Security Amendment 1: Galois Counter Mode—Advanced Encryption Standard—256 (GCM-AES-256) Cipher Suite	YES	If IEEE 802.1AE™-2006 is used then this is mandatory.
IEEE 802.1AEbwTM-2013	IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Security Amendment 2: Extended Packet Numbering	YES	If IEEE 802.1AE™-2006 is used then this is mandatory.
IEEE P802.1AEcg/D1.5, October 25, 2016	IEEE Draft Standard for Local and metropolitan area networks—Media Access Control (MAC) Security Amendment 3: Ethernet Data Encryption devices	YES	If IEEE 802.1AE™-2006 is used then this is mandatory.
IEEE 802.1AR™-2009	IEEE Standard for Local and metropolitan area networks – Secure Device Identity	YES	If IEEE 802.1AE™-2006 is used then this is mandatory.
IEEE 802.1X™-2010	IEEE Standard for Local and metropolitan area networks – Port Based Network Access Control	YES	Optional
IEEE 802.1Xbx-2014	IEEE Standard for Local and metropolitan area networks – Port Based Network Access Control Amendment 1: MAC Security Key Agreement Protocol (MKA) Extensions	YES	Optional

223

224 The IEEE P802.1AEcg enables multiple, per traffic class, transmit secure channels for MAC
225 and thus will also meet strict ordering requirements (within traffic class, with express or
226 preemptible transmission being selected for all the priorities allocated to a traffic class) for
227 preemption.

228 Secure Device Identifiers (DevIDs) are designed to be used as interoperable secure device
229 authentication credentials with Extensible Authentication Protocol (EAP) and other industry
230 standard authentication and provisioning protocols.

231 **4.3.4 Other IEEE 802.1 standard selections**

232 Table 11 specifies the other IEEE 802.1 standard selections.

233 **Table 11 – Other IEEE 802.1 standard selections**

Amendment	Title	Presence	Constraints
IEEE 802.1AB™-2016	IEEE Standard for Local and metropolitan area networks—Station and Media Access Control Connectivity Discovery	YES	–
IEEE 802.1AC™-2016	IEEE Standard for Local and metropolitan area networks— Media Access Control (MAC) Service Definition	YES	–
IEEE 802.1AX™-2008	IEEE Standard for Local and metropolitan area networks—Link Aggregation	NO	–

Amendment	Title	Presence	Constraints
IEEE 802.1BR™-2012	IEEE Standard for Local and metropolitan area networks—Virtual Bridged Local Area Networks—Bridge Port Extension	NO	–
IEEE 802.1CB™-2017	IEEE Standard for Local and Metropolitan Area Networks – Frame Replication and Elimination for Reliability	YES	Optional
IEEE P802.1CS/D1.5	IEEE Standard for Local and metropolitan area networks—LRP (Registration)	YES	–

234

235 **4.3.5 Other profiles**

236 A vendor can decide to implement more than one profile per device. In this case the
237 implemented profiles shall be coexistent. Table 12 shows other profiles.

238

Table 12 – Other IEEE 802.1 TSN profiles

Amendment	Title	Presence	Constraints
IEEE 802.1BA™-2011	IEEE Standard for Local and metropolitan area networks—Audio Video Bridging (AVB) Systems	YES	Optional; Coexistent with this profile contribution.
IEEE 802.1CM, 2018	IEEE Standard for Local and metropolitan area networks—Time-Sensitive Networks for Fronthaul	YES	Optional; Coexistent with this profile contribution.

239

240 **4.3.6 Management selection**

241 **4.3.6.1 General**

242 End stations and bridges shall provide at least the managed objects, which are required by this
243 profile contribution, from

244 IEEE 802.3

245 IEEE 802.3br

246 IEEE 802.1Q

247 IEEE 802.1Qca

248 IEEE 802.1Qcc

249 IEEE 802.1CBcv

250 IEEE 802.1AS

251 IEEE 802.1AB

252 IETF RFC 1213

253 etc.

254 These managed objects shall be represented preferred in the YANG format; if the YANG (RFC
255 6020) format is not available then MIB format (RFC 2358) shall be provided.

256 **4.3.6.2 Protocols**

257 Required access protocols are SNMP (RFC 4789) for a MIB representation and NETCONF
258 (RFC 6241) for YANG representation of the device local data base.

259

260 **5 Industrial Automation**

261 This standard is concerned with the requirements of Industrial Automation and meeting these
262 requirements with a bridged network. This clause gives an overview on Industrial Automation
263 and describes Industrial Automation requirements.

264 **5.1 Overview**

265 This subclause provides an introductory overview for the description of Industrial Automation
266 requirements to bridged networks provided in 6.2.

267 **5.1.1 Control Loop Basic Model**

268 Control loops are fundamental building blocks of industrial automation systems. Control loops
269 include: process sensors, a controller function, and output signals. Control loops may require
270 guaranteed low latency or more relaxed bounded latency network transfer quality.

271 To achieve the needed quality for Control loops the roundtrip delay of the exchanged data is
272 essential.

273 shows the whole transmission path from Controller application to Device application(s) and
274 back. The blue and red arrows show the contributions to the e2e (end-to-end) latency
275 respectively.

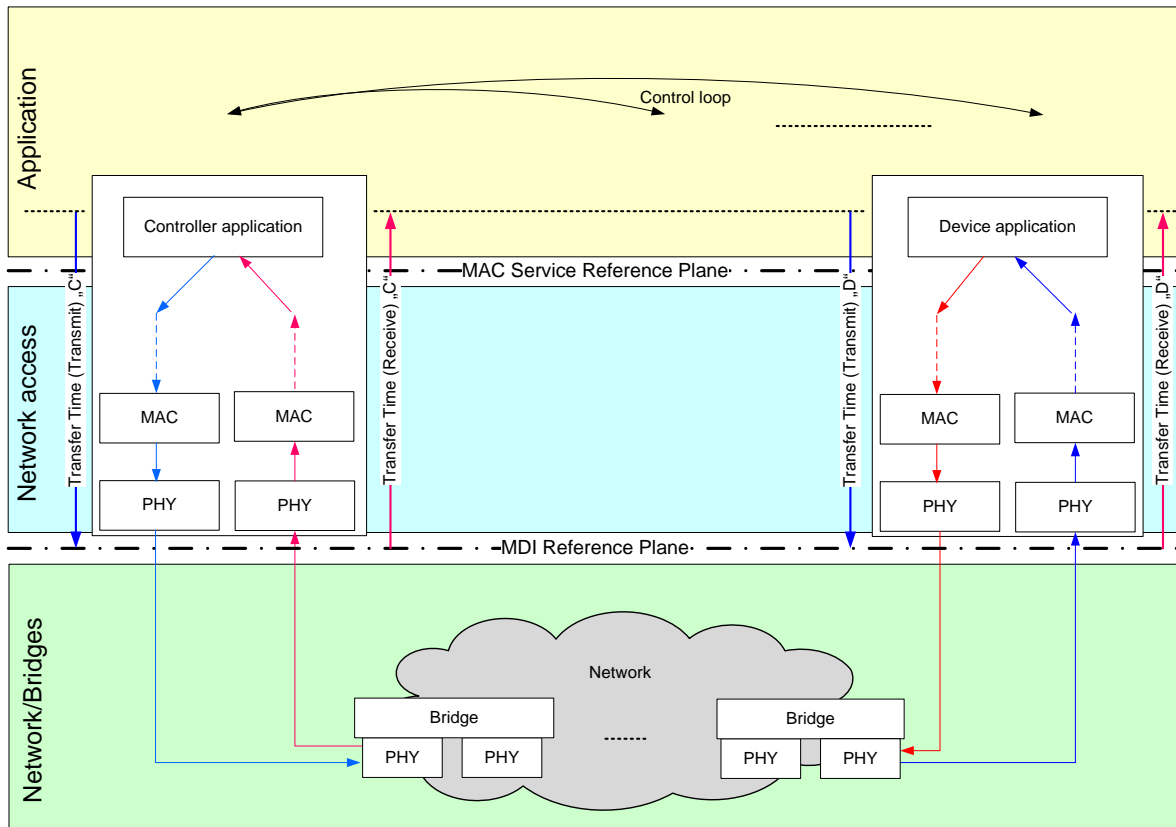
276 and show three levels of a control loop:

- 277 • Application - within End Station,
- 278 • Network Access - within End Station,
- 279 • Network / Bridges - within Bridges.

280 Applications may or may not be synchronized to the Network Access depending on the
281 application requirements. Applications which are synchronized to Network Access are called
282 “isochronous applications”. Applications which are not synchronized to Network Access are
283 called “non-isochronous applications”.

284 Network Access shall be synchronized to a common working clock or to a local timescale.

285 Network / Bridges may or may not be synchronized to a common working clock depending on
286 whether the Enhancements for Scheduled Traffic (IEEE 802.1Q-2018) are applied.



287

288

Figure 1 – Principle data flow of control loop

289 Transfer Times contain PHY and MAC delays. Both delays are asymmetric and vendor specific.
290 Device vendors have to take into account these transfer times when their application cycle
291 models are designed (see).

292 **Table 13 – Application types**

Level	Isochronous Application		Non-isochronous Application		
Application	Synchronized to network access		Synchronized to local timescale		
Network access	Synchronized to working clock, Stream Class based scheduling, Preemption				Synchronized to local timescale, Stream Class based scheduling, Preemption
Network/Bridges	Synchronized to working clock	Free running	Synchronized to working clock	Free running	Free running
	Scheduled traffic + Strict Priority + Preemption	Strict Priority or other Shaper + Preemption	Scheduled traffic + Strict Priority + Preemption	Strict Priority or other Shaper + Preemption	Strict Priority or other Shaper + Preemption

293
294 **5.1.2 Industrial Traffic Types**
295 Industrial automation applications concurrently make use of different traffic schemes/patterns
296 for different functionalities, e.g. parameterization, control, alarming. The various traffic patterns
297 have different characteristics and thus impose different requirements on a TSN network.

298 Table 3 subsumes the industrial automation relevant traffic patterns to traffic types with their
299 associated properties.

300 **Table 14 – Industrial automation traffic types summary**

Traffic type name	Periodic/ Sporadic	Guarantee	Data size	Redundancy
Isochronous cyclic real-time	P	Deadline/ bounded latency (e.g. 20% @ 1 Gbps / 50% @ 100 Mbit/s network cycle)/ bandwidth	Bounded	Up to seamless ¹⁾
Cyclic real-time	P	Deadline/ bounded latency (e.g. n-times network cycle)/ bandwidth	Bounded	Up to seamless ¹⁾
Network control	S	Priority	—	Up to seamless ¹⁾ as required
Audio/video	P	Bounded latency/ bandwidth	Bounded	Up to seamless ¹⁾ as required
Brownfield	P	Bounded latency/ bandwidth	-	Up to regular ²⁾
Alarms/ events	S	Bounded latency/ bandwidth	-	Up to regular ²⁾
Configuration/ diagnostics	S	Bandwidth	-	Up to regular ²⁾
Internal / Pass- through	S	Bandwidth	-	Up to regular ²⁾

Best effort	S	-	-	Up to regular ²⁾
¹⁾ almost zero failover time; ²⁾ larger failover time because of network re-convergence				

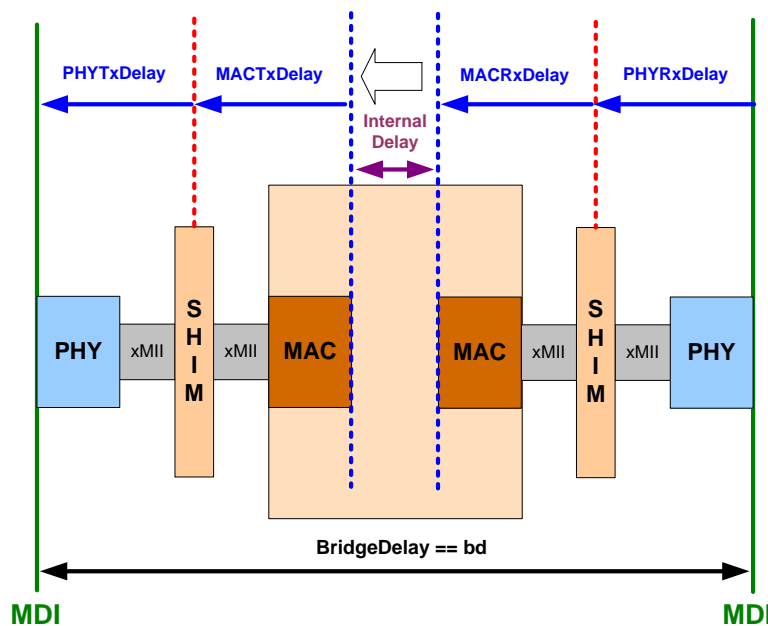
301

302 **5.2 Requirements**

303 This subclause summarizes Industrial Automation requirements to bridged networks.

304 **5.2.1 Bridge delay requirements**

305 Figure 2 shows the definition the Bridge delay reference points. To make short control loop
 306 times feasible Bridge-delays shall be independent from the frame size and meet the upper limits
 307 of Table 15.



308

309

Figure 2 – Delay measurement reference points

310

311

Table 15 – Required Ethernet Bridge delays

Data rate	Value	Comment
10 Mbps	< 30 μ s	Bridge delay measure from MII to MII ¹⁾
100 Mbps	< 3 μ s	Bridge delay measure from MII to MII ¹⁾
1 Gbps	< 1 μ s	Bridge delay measure from RGMII to RGMII ¹⁾
2,5 Gbps	< 1 μ s	Bridge delay measure from XGMII to XGMII ¹⁾
5 Gbps	< 1 μ s	Bridge delay measure from XGMII to XGMII ¹⁾
10 Gbps	< 1 μ s	Bridge delay measure from XGMII to XGMII ¹⁾
25 Gbps – 1 Tbps:	< 1 μ s	Bridge delay measure from XGMII to XGMII ¹⁾
¹⁾ first bit in, first bit out		

312

313 **5.2.2 Network access**

314 The following network access features for end stations according to IEEE 802.1 shall be
 315 supported:

- 316 a) Synchronization to working clock;
- 317 b) Stream class based scheduling with:
- 318 o Network cycle,
- 319 - < 50 % bandwidth per link for < 1 Gbps for streams;
- 320 - < 20 % bandwidth per link for >= 1 Gbps for streams;
- 321 - < 25 % bandwidth per link for non-streams;
- 322 o Reduction ratio;
- 323 o Phase;
- 324 o Sequence;
- 325 o Transmit of frames as a convoy starts at network cycle start with minimum interpacket
- 326 gap (IPG); first isochronous cyclic real-time frames, second cyclic real-time frames, third
- 327 non-stream frames;
- 328 o Reception of frames before assigned network cycle based deadline;
- 329 c) Time limits for transfer time (receive), see , shall be <= 3 μs in addition to PHY-delay and
- 330 MAC-delay;
- 331 d) Time limits for transfer time (transmit), see , shall be <= 3 μs in addition to PHY-delay and
- 332 MAC-delay;
- 333 e) Network access parameters:
- 334 o NetworkCycle according to Table 16,
- 335 o ReductionRatio according to Formula (1),
- 336 o Phase according to Formula (2),
- 337 o Sequence according to Formula (3).
- 338

Table 16 – Values of the parameter NetworkCycle

NetworkCycle [time]	10 Mb/s [Data rate]	100 Mb/s [Data rate]	≥ 1 Gb/s [Data rate]
31,25 μs	n.a.	n.a.	Together with all ReductionRatios
62,5 μs	n.a.	n.a.	Together with all ReductionRatios
125 μs	n.a.	n.a.	Together with all ReductionRatios
250 μs	n.a.	Together with all ReductionRatios	Together with all ReductionRatios
500 μs	n.a.	Together with all ReductionRatios	Together with all ReductionRatios
1 ms	Together with ReductionRatio ≥ 8	Together with all ReductionRatios	Together with all ReductionRatios
2 ms	n.a.	Together with all ReductionRatios	n.a.
4 ms	n.a.	Together with all ReductionRatios	n.a.

340

341 The ReductionRatio shall be created according to Formula (1).

$$\text{ReductionRatio} = 2^n \mid n \in \mathbb{N}_0 \mid n \leq 10(1)$$

Where

ReductionRatio is the result of the operation
 n is actual factor for the operation
 \mathbb{N}_0 are the natural numbers including zero

342

343 The Phase shall be created according to Formula (2).

PhaseNumber = 1 to ReductionRatio (2)

Where

PhaseNumber is the chosen one out the list
ReductionRatio is the applied ReductionRatio

344

345 The Sequence shall be created according to Formula (3).

SequenceNumber = 1 to MaxListLength (3)

Where

SequenceNumber is the chosen one out the list
MaxListLength is the maximum possible entries per Phase

346 5.2.3 Bridge FDB requirements

347 Editor's note: Contribution requested.

348 5.2.4 Bridge resource requirements

349 Editor's note: Contribution requested.

350 5.2.5 Quantities

351 The following quantities shall be supported in a single TSN domain:

- 352 a) Stations: $\geq 1\ 024$
- 353 b) Network diameter: ≥ 64
- 354 c) Streams per PLC for Controller-to-Device (C2D) communication:
 - 355 – ≥ 512 talker and ≥ 512 listener streams;
 - 356 – $\geq 1\ 024$ talker and $\geq 1\ 024$ listener streams in case of seamless redundancy;
- 357 d) Streams per PLC for Controller-to-Controller (C2C) communication:
 - 358 – ≥ 64 talker and ≥ 64 listener streams;
 - 359 – ≥ 128 talker and ≥ 128 listener streams in case of seamless redundancy.
- 360 e) Streams per Device for Device-to-Device (D2D) communication:
 - 361 – ≥ 2 talker and ≥ 2 listener streams;
 - 362 – ≥ 4 talker and ≥ 4 listener streams in case of seamless redundancy.

363 Example calculation of data flow quantities for eight PLCs – without seamless redundancy:

- 364 ○ $8 \times 512 \times 2$ = 8 192 streams for C2D communication, plus
- 365 ○ $8 \times 64 \times 2$ = 1 024 streams for C2C communication
- 366 ○ $(8\,192 + 1\,024) \times 2\,000$ = 18 432 000 Bytes data of all streams

367 **5.2.6 Synchronization requirements**

368 Synchronization covering both universal time and working clock timescales is needed for
369 industrial automation systems.

370 Redundancy for synchronization of universal time may be solved with “cold standby”. Support
371 of "Hot standby" for universal time synchronization is not current practice - but is an option in
372 this document and can be used depending on the application requirements.

373 Redundancy for Working Clock synchronization can be solved with “cold standby” or “hot
374 standby” depending on the application requirements. Support of "hot standby" for working clock
375 synchronization is required.

376 NOTE Global Time is often used as synonym term for “Universal Time”. Wall Clock is based on Universal Time and
377 considers time zones, daylight saving time and leap seconds.

378 **5.2.6.1 Universal Time synchronization**

379 Universal time is used to plant wide align events and actions (e.g. for “sequence of events”).
380 The assigned timescale is TAI, which can be converted into local date and time if necessary.
381 The goal of Universal Time synchronization is to establish a worldwide aligned timescale for
382 time. Thus, often satellites are used as source of the time.

383 **5.2.6.2 Working Clock synchronization**

384 Working Clock is used to align actions line, cell or machine wide. The assigned timescale is
385 ARB. Robots, motion control, numeric control and any kind of clocked / isochronous application
386 rely on this timescale to ensure that actions are precisely interwoven as needed. Often PLCs,
387 Motion Controller or Numeric Controller are used as Working Clock source.

388 Working Clock domains may be doubled to support zero failover time for synchronization by
389 aligning the both timescales at the Grandmaster.

390 **TBD: two WC domains – needs more definitions – hot standby/cold standby need
391 definitions**

392 High precision Working Clock synchronization is a prerequisite for control loop implementations.

393 **5.2.6.3 General Requirements for Synchronization**

394 Synchronization domain settings shall be according to and .

395 **Table 17 – Synchronization Domains**

Domain	ID	Timescales	Presence	Constraints
Working Clock	20	ARB	YES	Used for network access and application synchronization. If scheduled traffic is used then also used for Bridge synchronization.
Universal Time	0	TAI	YES	Used for Universal Time.
Redundant Working Clock	21	ARB	YES	Used for hot standby of Working Clock. Timescale shall be identical to Working Clock.
Redundant Universal Time	1	TAI	YES	Optional. Used for hot standby of Universal Time. Timescale shall be identical to Universal Time.

396 **TBD: ID is Domain number – all Timescales coded as PTP**

397 In the working clock domain bridges shall take the roles of time aware relay and time aware
398 endpoint, because they shall be in sync for scheduled traffic transmission.

399 In the Universal Time domain the role of a time aware relay is mandatory and the role of a time
400 aware endpoint is optional for Bridges.

401 At least one grandmaster shall be present in every synchronization domain.

402 All members of a synchronization domain may take at least one of the roles specified in .

403 **Table 18 – Synchronization Roles**

Role	Working Clock		Universal Time	
	Bridge or Router	End Station	Bridge or Router	End Station
Time aware relay	mandatory	–	mandatory	–
Time aware endpoint	mandatory	mandatory	optional	mandatory
Grandmaster capable	Optional	optional	optional	optional

404 *Editor Note: is support of UniversalTime/Time aware endpoint mandatory or optional for end*
405 *stations? Contributions are welcome.*

406 The requirements concerning the overall maximum deviation to the grandmaster time in the
407 synchronization domains in shall be fulfilled.

408 **Table 19 – Maximum deviation to grandmaster time requirements**

Domain	Maximum absolute value of deviation from grandmaster time	Comments
Working Clock	< 1 μ s	Maximum deviation +/- 1 μ s
Universal Time	< 100 μ s	Maximum deviation +/- 100 μ s

409 **Editor’s Note: reference number of hops (100) – “grandmaster time” must be defined –**
410 **from TAI in case of universal time**

411 shows the number of hops which shall be supported.

412 **Table 20 – Maximum number of hops between grandmaster and time aware end-point**

Domain	Number of hops	Comments
Working Clock	100	Grandmaster to time aware end-point. May be 200 between two time aware end-points.
Universal Time	100	From Grandmaster connected to the satellite receiver to each time aware endpoint.

413

414 The maximum working clock deviation between two devices, which are synchronized to the
415 same grandmaster, shall be < 2 μ s when the working clock requirement of is observed.

416 The maximum error contribution of every single network node of the domains shall be according
417 to .

418 **Table 21 – Maximum error contribution per network node**

Error contribution	Max. error	Comments
Maximum residence time error	< 10 ns	Externally measured from the MDI to MDI at the local Bridge.
Maximum link delay error	< 10 ns	Externally measured from the MDI to MDI at the local link – including the asymmetry error contribution.

419 Minimal timestamp accuracy for any kind of timestamp shall be according to .

420

Table 22 – Timestamp accuracy

Timestamp	Accuracy	Comments
Working Clock	≤ 8 ns	—
Universal time	≤ 8 ns	—

421 Table 9 specifies the clock synchronization profile contribution. The selection of the different
422 clock types per device shall be provided using PICS.

423 **Editor's Note: add requirement about asymmetry compensation**

424

425

426 **6 Industrial Automation profile**

427 The objective of the Industrial Automation profile specified in this standard is to allow the
428 construction of bridged networks that meet the industrial automation requirements described in
429 Clause 5.

430 The bridges of an industrial automation bridged network shall meet the bridge requirements
431 specified in Clause 4 and each link of an industrial automation bridged network is a full duplex
432 point-to-point link. Furthermore, the industrial automation bridged network is designed,
433 configured, and operated as described in this clause in order to meet the industrial automation
434 requirements described in Clause 5. The end stations of an industrial automation deployment
435 shall meet the end station requirements specified in Clause 4 in order to meet the industrial
436 automation requirements described in Clause 5.

437

438 **6.1 Frame size**

439 The size of the Ethernet frames can influence whether or not the industrial automation
440 requirements are met.

441 The maximum frame size is configured at each port of the industrial automation bridged network
442 according to the maximum frame size rules that apply to IEEE 802.3 frames. That is, the
443 maximum possible frame size from the destination MAC address through the end of the CRC is
444 2000 octets. For example, if nothing but the basic IEEE 802.3 headers are being used with an
445 IEEE 802.1Q C-VLAN tag, then the maximum frame size is 1522 octets. The maximum frame
446 size applied in a network can be smaller than the maximum frame size allowed by IEEE Std
447 802.3. Furthermore, the maximum frame size applied for different traffic classes can be
448 different. The maximum frame size actually applied for the different traffic classes is used in
449 worst-case latency calculations.

450 **6.2 Traffic classes**

451

452 **6.3 Latency**

453

454 **6.4 Frame loss**

455

456 **6.5 VLANs**

457

458 **6.6 Synchronization**

459 Redundancy for synchronization of universal time may be solved with “cold standby”. Support
460 of "Hot standby" for universal time synchronization is not current practice - but is an option in
461 this document and can be used depending on the application requirements.

462 Redundancy for Working Clock synchronization can be solved with “cold standby” or “hot
463 standby” depending on the application requirements. Support of "hot standby" for working clock
464 synchronization is required.

465 Working Clock domains may be doubled to support zero failover time for synchronization by
466 aligning the both timescales at the Grandmaster.

467

468 All members of a synchronization domain may take at least one of the roles specified in .

469

Table 23 – Synchronization Roles

Role	Working Clock		Universal Time	
	Bridge or Router	End Station	Bridge or Router	End Station
Time aware relay	mandatory	–	mandatory	–
Time aware endpoint	mandatory	mandatory	optional	mandatory
Grandmaster capable	Optional	optional	optional	optional

470 *Editor Note: is support of UniversalTime/Time aware endpoint mandatory or optional for end*
471 *stations? Contributions are welcome.*

472

473 **6.7 Security**

474 IEEE Std 802.1AE enables multiple, per traffic class, transmit secure channels for MAC and
475 thus will also meet strict ordering requirements (within traffic class, with express or preemptible
476 transmission being selected for all the priorities allocated to a traffic class) for preemption.

477 Secure Device Identifiers (DevIDs) are designed to be used as interoperable secure device
478 authentication credentials with Extensible Authentication Protocol (EAP) and other industry
479 standard authentication and provisioning protocols.

480

481

Annex A

PCS proforma – Time-sensitive networking profile for industrial automation

A.1 General

The supplier of an implementation that is claimed to conform to a particular profile defined in this standard shall complete the corresponding Profile Conformance Statement (PCS) proforma, which is presented in a tabular format based on the format used for Protocol Implementation Conformance Statement (PICS) proformas.

The tables do not contain an exhaustive list of all requirements that are stated in the referenced standards; for example, if a row in a table asks whether the implementation is conformant to Standard X, and the answer “Yes” is chosen, then it is assumed that it is possible, for that implementation, to fill out the PCS proforma defined in Standard X to show that the implementation is conformant; however, the tables in this standard will only further refine those elements of conformance to Standard X where particular answers are required for the profiles defined here.

The profiles are not intended to be mutually exclusive; it is possible that a given implementation can support more than one of the profiles defined in this standard. If that is the case, then either the PCS for the implementation should be filled out in order to reflect the support of multiple profiles, or a separate PCS should be filled out to reflect each profile supported.

A completed PCS proforma is the PCS for the implementation in question. The PCS is a statement of which capabilities and options of the protocol have been implemented. The PCS can have a number of uses, including use by the following:

- a) Protocol implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;
- b) Supplier and acquirer—or potential acquirer—of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PCS proforma;
- c) User—or potential user—of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PCSs);
- d) Protocol tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A.2 Abbreviations and special symbols

A.2.1 Status symbols

M: mandatory

O: optional

O.n: optional, but support of at least one of the group of options labeled by the same numeral n is required

X: prohibited

pred: conditional-item symbol, including predicate identification: see A.3.4

¬ logical negation, applied to a conditional item’s predicate

A.2.2 General abbreviations

N/A: not applicable

PCS: Profile Conformance Statement

527 **A.3 Instructions for completing the PCS proforma**

528 **A.3.1 General structure of the PCS proforma**

529 The first part of the PCS proforma, implementation identification and protocol summary, is to
530 be completed as indicated with the information necessary to identify fully both the supplier and
531 the implementation.

532 The main part of the PCS proforma is a fixed-format questionnaire, divided into several
533 subclauses, each containing a number of individual items. Answers to the questionnaire items
534 are to be provided in the rightmost column, either by simply marking an answer to indicate a
535 restricted choice (usually Yes or No) or by entering a value or a set or range of values. (Note
536 that there are some items where two or more choices from a set of possible answers can apply;
537 all relevant choices are to be marked.) Each item is identified by an item reference in the first
538 column. The second column contains the question to be answered; the third column records the
539 status of the item—whether support is mandatory, optional, or conditional; see also A.3.4. The
540 fourth column contains the reference or references to the material that specifies the item in the
541 main body of this standard, and the fifth column provides the space for the answers.

542 A supplier may also provide (or be required to provide) further information, categorized as either
543 Additional Information or Exception Information. When present, each kind of further information
544 is to be provided in a further subclause of items labeled A_i or X_i , respectively, for cross-
545 referencing purposes, where i is any unambiguous identification for the item (e.g., simply a
546 numeral). There are no other restrictions on its format and presentation.

547 A completed PCS proforma, including any Additional Information and Exception Information, is
548 the Protocol Implementation Conformation Statement for the implementation in question.

549 NOTE Where an implementation is capable of being configured in more than one way, a single PCS may be able
550 to describe all such configurations. However, the supplier has the choice of providing more than one PCS, each
551 covering some subset of the implementation's configuration capabilities, in case that makes for easier and clearer
552 presentation of the information.

553 **A.3.2 Additional information**

554 Items of Additional Information allow a supplier to provide further information intended to assist
555 the interpretation of the PCS. It is not intended or expected that a large quantity will be supplied,
556 and a PCS can be considered complete without any such information. Examples might be an
557 outline of the ways in which a (single) implementation can be set up to operate in a variety of
558 environments and configurations, or information about aspects of the implementation that are
559 outside the scope of this standard but that have a bearing on the answers to some items.

560 References to items of Additional Information may be entered next to any answer in the
561 questionnaire and may be included in items of Exception Information.

562 **A.3.3 Exception Information**

563 It may occasionally happen that a supplier will wish to answer an item with mandatory status
564 (after any conditions have been applied) in a way that conflicts with the indicated requirement.
565 No preprinted answer will be found in the Support column for this item. Instead, the supplier
566 shall write the missing answer into the Support column, together with an X_i reference to an item
567 of Exception Information, and shall provide the appropriate rationale in the Exception item itself.

568 An implementation for which an Exception item is required in this way does not conform to this
569 standard.

570 NOTE A possible reason for the situation described previously is that a defect in this standard has been reported,
571 a correction for which is expected to change the requirement not met by the implementation.

572 **A.3.4 Conditional status**

573 **A.3.4.1 Conditional items**

574 The PCS proforma contains a number of conditional items. These are items for which both the
575 applicability of the item itself, and its status if it does apply—mandatory or optional—are
576 dependent on whether certain other items are supported.

577 Where a group of items is subject to the same condition for applicability, a separate preliminary
578 question about the condition appears at the head of the group, with an instruction to skip to a
579 later point in the questionnaire if the “Not Applicable” (N/A) answer is selected. Otherwise,
580 individual conditional items are indicated by a conditional symbol in the Status column.

581 A conditional symbol is of the form “pred: S” where pred is a predicate as described in A.3.4.2,
582 and S is a status symbol, M or O.

583 If the value of the predicate is true (see A.3.4.2), the conditional item is applicable, and its
584 status is indicated by the status symbol following the predicate: The answer column is to be
585 marked in the usual way. If the value of the predicate is false, the “Not Applicable” (N/A) answer
586 is to be marked.

587 **A.3.4.2 Predicates**

588 A predicate is one of the following:

- 589 a) An item-reference for an item in the PCS proforma: The value of the predicate is true if the
590 item is marked as supported and is false otherwise.
- 591 b) A predicate-name, for a predicate defined as a Boolean expression constructed by
592 combining item-references using the Boolean operator OR: The value of the predicate is
593 true if one or more of the items is marked as supported.
- 594 c) The logical negation symbol “¬” prefixed to an item-reference or predicate-name: The value
595 of the predicate is true if the value of the predicate formed by omitting the “¬” symbol is
596 false, and vice versa.

597 Each item whose reference is used in a predicate or predicate definition, or in a preliminary
598 question for grouped conditional items, is indicated by an asterisk in the Item column.

599 **A.3.4.3 References to other standards**

600 The following shorthand notation is used in the References columns of the profile tables:

601 <standard abbreviation>:<clause-number>

602 where standard abbreviation is one of the following:

603 Q: IEEE Std 802.1Q

604 AS: P802.1AS-REV

605 Dot3: IEEE Std 802.3

606 Hence, a reference to “IEEE Std 802.1Q-2018, 5.4.2” would be abbreviated to “Q:5.4.2”

607 **A.4 Common requirements**

608 **A.4.1 Implementation identification**

609 The entire PCS pro forma is a form that shall be filled out by a supplier.

610

Supplier	
Contact point for queries about the PCS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification, e.g., name(s) and version(s) of machines and/or operating system names	

611

612 Only the first three items are required for all implementations; other information may be
613 completed as appropriate in meeting the requirement for full identification.

614 NOTE The terms “Name” and “Version” should be interpreted appropriately to correspond with a supplier’s
615 terminology (e.g., Type, Series, Model).

616 **A.4.2 Profile summary, IEC/IEEE 60802**

Identification of profile specification	IEC/IEEE 60802 - Time-Sensitive Networking Profile for Industrial Automation			
Identification of amendments and corrigenda to the PCS proforma that have been completed as part of the PCS	Amd.	:	Corr.	:
	Amd.	:	Corr.	:
Have any Exception items been required? (See A.3.3: the answer “Yes” means that the implementation does not conform to IEC/IEEE 60802)	No	[]	Yes	[]
Date of Statement				

617

618 **A.4.3 Implementation type**

619 This form is used to indicate the type of system that the PCS describes.

620

Item	Feature	Status	References	Support	
BGE	Is the implementation a Bridge?	O.1		Yes []	No []
TLK	Is the implementation a Talker end station?	O.1		Yes []	No []
LSN	Is the implementation a Listener end station?	O.1		Yes []	No []

621 NOTE a single device can incorporate the functionality of one or more of the functions listed in this table. For
622 example, a device could have both Talker end station and Listener end station capability.

623 **A.4.4 Common requirements— PHY and MAC**

Item	Feature	Status	References	Support	
Dot3	Does one or more Port of the device support an IEEE 802.3 MAC?	M		Yes []	No []
Dot3-1	State the number of IEEE802.3cg Ports.	O.2		Number_____	
Dot3-2	State the number of 100 Mb/s Ports.	O.2		Number_____	
Dot3-3	State the number of 1 Gb/s Ports.	O.2		Number_____	
Dot3-4	State the number of 2,5 Gb/s Ports.	O.2		Number_____	
Dot3-5	State the number of 5 Gb/s Ports.	O.2		Number_____	
Dot3-6	State the number of 10 Gb/s or greater Ports.	O.2		Number_____	
Dot3-7	State the number of Ports supporting IEEE802.3bw-2015	O.2		Number_____	
Dot3-8	State the number of Ports supporting IEEE802.3by-2016	O.2		Number_____	
Dot3-9	State the number of Ports supporting IEEE802.3bq-2016	O.2		Number_____	
Dot3-10	State the number of Ports supporting IEEE802.3bp-2016	O.2		Number_____	

Dot3-11	State the number of Ports supporting IEEE802.3br-2016	M		Number_____	
Dot3-12	State the number of Ports supporting IEEE802.3bz-2016	O.2		Number_____	
Dot3-10	State the number of Ports supporting IEEE802.3bs /D2.2	O.2		Number_____	
Dot3-11	State the number of Ports supporting IEEE802.3bt /D2.2	O		Number_____	
Dot3-12	State the number of Ports supporting IEEE802.3bu /D3.3	O		Number_____	
Dot3-13	State the number of Ports supporting IEEE802.3bv /D3.3	O.2		Number_____	
Dot3-14	State the number of Ports supporting IEEE802.3ca /D0.0	O.2		Number_____	
Dot3-15	State the number of Ports supporting IEEE802.3cb /D2.1	O.2		Number_____	
Dot3-16	State the number of Ports supporting IEEE802.3cc /D2.0	O.2		Number_____	
Dot3-17	State the number of Ports supporting IEEE802.3cd /D1.1	O.2		Number_____	
Dot3-19	Do all the IEEE 802.3 Ports support full duplex operation?	M		Yes []	No []
Dot3-20	Do all ports support a maximum frame size of 2000 octets?	M		Yes []	No []

624

625 **A.4.5 Common requirements— Bridges**

626 If item BGE in A.4.3 is supported, then the Support column in ZZZZ through ZZZZ shall be
627 completed; otherwise the support column items in these tables shall be left blank.

628 The major capabilities to be supported in all Bridges are identified in ZZZZ. An Bridge shall
629 support all mandatory requirements that apply to a VLAN-aware Bridge component, and to
630 support IEEE Std 802.1AS.

631 Additional requirements for IEEE 802.1Q implementation that apply to all Bridges are identified
632 in ZZZZ. These cover detailed requirements for tagging, VID, FID, MSRP, and forwarding
633 support.

634 Additional requirements for IEEE 802.1AS implementation that apply to all AV Bridges are
635 identified in ZZZZ.

636 **A.4.6 Major capabilities—Bridges**

637

Item	Feature	Status	References	Support	
BGE-1	Do all ports support a maximum frame size of 2000 octets?	M	4.3.2.1.1	Yes []	No []
BGE-2	Does the Bridge support disabling of priority-based flow control?	M	4.3.2.1.1	Yes []	No []
BGE-3	Does the Bridge support disabling MAC control PAUSE if implemented?	M	4.3.2.1.1	Yes []	No []
BGE-4	Does the Bridge support disabling of Energy Efficient Ethernet?	M	4.3.2.1.1	Yes []	No []
BGE-5	Does the Bridge support the strict priority algorithm on each port?	M	4.3.2.1.1	Yes []	No []

BGE-6	Does the Bridge support 8 queues on each port?	M	4.3.2.1.1	Yes []	No []
BGE-7	Does the Bridge support priority regeneration?	M	4.3.2.1.1	Yes []	No []
BGE-8	Does the Bridge support preemption?	M	4.3.2.1.1	Yes []	No []
BGE-9	Does the Bridge meet the bridge delays specified in 5.2.1?	M	Table 15	Yes []	No []

638

639 **A.4.7 IEEE Std 802.1Q requirements—Bridges**

Item	Feature	Status	References	Support	
B-Q-1	Does the Bridge support requirements for VLAN Bridge Components per IEEE802.1Q 5.4 and Table 7?	M	4.3.2.1.1 Table 7	Yes []	No []
B-Q-2	Does the Bridge support requirements for VLAN Bridge per IEEE802.1Q 5.4.1 and Table 7?	M	4.3.2.1.1 Table 7	Yes []	No []
B-Q-3	Does the Bridge support MST operation per IEEE802.1Q 5.4.1.1 and Table 7?	M	Table 7	Yes []	No []
B-Q-4	Does the Bridge support MMRP operation per IEEE802.1Q 5.4.1.3 and Table 7?	O	4.3.2.1.1 Table 7	Yes []	No []
B-Q-5	State the number of Ports supporting Enhancements for scheduled traffic per IEEE802.1Q 5.4.1 and Table 7	O	Table 7	Number_____	
B-Q-6	State the number of Ports supporting FQSS per IEEE802.1Q 5.4.1.5 and Table 7	O	Table 7	Number_____	
B-Q-7	State the number of Ports supporting PSFP per IEEE802.1Q 5.4.1.8 and Table 7	O	Table 7	Number_____	
B-Q-8	State the number of Ports supporting CQF per IEEE802.1Q 5.4.1.9 and Table 7	O	Table 7	Number_____	
B-Q-9	Does the Bridge support MVRP per IEEE802.1Q 5.4.2 and Table 10?	O	Table 7	Yes []	No []
B-Q-10	Does the Bridge support MSRP per IEEE802.1Q 5.4.4 and Table 7?	O	4.3.2.1.1 Table 7	Yes []	No []
B-Q-11	Does the Bridge support C-VLAN requirements per IEEE802.1Q 5.5, 5.9 and Table 7?	O	4.3.2.1.1 Table 7	Yes []	No []
B-Q-12	Does the Bridge support MAC Bridge component requirements per IEEE802.1Q 5.13, 5.14 and Table 7?	O	4.3.2.1.1 Table 7	Yes []	No []
B-Q-13	State the number of Asynchronous Traffic Shaping per IEEE P802.1Qcr D0.0 and Table 8	O	Table 8	Number_____	
B-Q-14	Does the Bridge support IEEE802.1Qcc-2018 per Table 8?	O	Table 8	Yes []	No []
B-Q-15	Does the Bridge support IEEE P802.1Qdd per Table 10?	O	Table 8	Yes []	No []

640

641 **A.4.8 Time Synchronization Requirements**

642

643

Item	Feature	Status	References	Support	
TS-1	Does the implementation support four domains as specified in ?	M		Yes []	No []
TS-2	Does the implementation comply with the maximum error contribution per network node specified in ?	M		Yes []	No []
TS-3	Does the implementation comply with the timestamp accuracy specified in ?	M		Yes []	No []
TS-4	Does the implementation comply with Time aware system requirements specified in AS: 5.3 and Table 9?	M	AS:5.3, Table 9	Yes []	No []
TS-5	Does the implementation comply with PTP instance requirements specified in AS: 5.4 and Table 9?	M	AS:5.4, Table 9	Yes []	No []
TS-5	Does the implementation comply with PTP instance requirements specified in AS: 5.4 and Table 9?	M	AS:5.4, Table 9	Yes []	No []
TS-6	List the number of ports supporting the media-independent master capability	O	AS:5.4.1, Table 9	Number_____	
TS-7	Is the implementation Grand Master capable as specified in AS: 5.4.1 and Table 9?	O	AS:5.4.1, Table 9	Yes []	No []
TS-8	List the number of ports supporting PTP Relay Instance capability	O	AS:5.4.2, Table 9	Number_____	
TS-9	Does the implementation support media-independent attributes of the Announce message and the Signaling message	O	AS:5.4.1, Table 9	Yes []	No []
TS-10	Does the implementation support the SyncIntervalSetting state machine	O	AS:5.4.1, Table 9	Yes []	No []
TS-11	Does the implementation support timing and synchronization management	M	AS:5.4.1, Table 9	Yes []	No []
TS-12	List the number of ports supporting MAC-specific timing and synchronization methods for IEEE 802.3 full-duplex links	M	AS:5.5, Table 9	Number_____	
TS-13	List the number of ports supporting MAC-specific timing and synchronization methods for IEEE 802.11	O	AS:5.6, Table 9	Number_____	

644

645

A.4.9 Security Requirements

Item	Feature	Status	References	Support	
SEC-1	Does the implementation support IEEE 802.1AE™- 2006?	O	Table 10	Yes []	No []
SEC-2	Does the implementation support IEEE 802.1AEbn™- 2011?	Dot1AE:M	Table 10	Yes []	No []
SEC-3	Does the implementation support IEEE 802.1AEbw™- 2013?	Dot1AE:M	Table 10	Yes []	No []
SEC-4	Does the implementation support IEEE 802.1AEcg?	Dot1AE:M	Table 10	Yes []	No []
SEC-5	Does the implementation support IEEE 802.1AR™- 2009?	Dot1AE:M	Table 10	Yes []	No []

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SEC-6	Does the implementation support IEEE 802.1X™- 2009?	<input type="radio"/>	Table 10	Yes []	No []
SEC-6	Does the implementation support IEEE 802.1Xbx™- 2014?	<input type="radio"/>	Table 10	Yes []	No []

646

647

648

649 **Annex Z**
650 **(informative/normative)**

651 **Gaps**
652

- 653 1. Regular synchronization of .1Qbv “tick” event to the 802.1AS-Rev clock
654 2. Distributed and Centralized model “UNI” may need to be expanded.
655 3. Need mechanism for identifying “In-sync” and “out of Sync” for all time-aware systems
656 in the network.
657 4. Network diagnostic – base on Gunter’s contribution.
658 5. Synchronization – base on Gunter’s contribution.
659 6. Defined range of destination MAC address, do we get our own OUI
660 7. Do we need a standardized TLV for LLDP to identify the TSN domain
661 8. Do we need a section to distinguish between constrained devices vs other devices?
662 9. Management Reconciliation
- 663 • <http://www.ieee802.org/1/files/public/docs2018/60802-Steindl-Configuration-0718-v02.pdf>
664
- 665 10. Need to identify network management access protocols and select data models for
666 management.
667 11. Bridge FDB and resource requirements
668 12. Define procedures to implement hot-stand-by masters.
669 13. Do we need an IEC/IEEE translation dictionary?
670 14. Reference style IEC guides in the profile.

671 **Editor’s note: Do we need a different class of device for constrained devices (two-port**
672 **mac relays for instance) or a separate profile? (Table 12-24 in 802.1Q-2018 has an**
673 **example of how this might be done)?**

- 674 15. Do we need to specify link aggregation in support of event-based control?
- 675 • <http://www.ieee802.org/1/files/public/docs2018/60802-stanica-event-based-control-1118-v02.pdf>
676
 - 677 • <http://www.ieee802.org/1/files/public/docs2018/60802-stanica-link-aggregation-1118-v02.pdf>
678
- 679 16. How do we deal with destination MAC address constraints
- 680 • <http://www.ieee802.org/1/files/public/docs2018/60802-Steindl-DaMacConstraints-0718-v02.pdf>
681

683

Bibliography

684

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686 *Networked Measurement and Control Systems*

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