CONTENTS

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 and 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 includes both Step 1 and Step 2.

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. This contribution assumes a single profile. Clause 6 should be sub-divided in case of multiple profiles.

Step 2: Conformance

Step 2 intends to improve conformance statements. Content of D1.0 was not intended to be changed. However, some additions have been made as part of the improvement attempt. Difference, mistakes in this contribution are because the difficulties this commenter had to figure out conformance statements from D1.0.

This contribution assumes a single profile. Additional conformance statements are needed in case of multiple profiles.

Conformance statements in Clause 6 of D1.0 are ambiguous, not precise. Conformance statements should be precise. There should be conformance statements relatively easy to read for a human being. This commenter considers D1.0 Annex A PCS machine-readable, or very close, from which it is an easy step to create further machine-readable formats at the end of the project. However, conformance statements in Clause 6 D1.0 are not friendly to a human reader because it is very difficult to figure out for a vendor what actually needs to be implemented.

It is not possible to refer to entries of tables in D1.0. For instance, in D1.0, the PCS can only refer to subclause or table number but not the specific entry that is meant. This proposal resolves the referencing issue.

For instance, if a vendor only implements end stations, then it is very difficult to figure out what must be implemented. The difficulty is the same for a bridge vendor. This reader ended up needing to open the referred standards to figure it out despite of trying various other method beforehand.

One of the methods this reader tied to figure out what needs to be implemented in case of being a bride vendor.

1) Check the mandatory features for bridges in Annex A PCS of D1.0

2) Follow the references provided by the PCS items

   It is understood that it is an early draft, references are not filled. However, references are not helpful in most of the cases.

   For instance, Annex A.4.6 Major capabilities—Bridges refers to subclause 6.2.1.1 General required Bridge features, which however, includes end station features as well. For example, B-Q-1 makes subclause 5.4 of IEEE Std 802.1Q mandatory; however, other conformance statements make some parts of subclause 5.4 of IEEE Std 802.1 optional. Furthermore, Annex A.4.6 just refers to Table 9 in 6.2.1.1 for all the mandatory and optional features. Nonetheless, Table 9 includes both mandatory and optional features, as well as features that are not relevant for IEC/IEEE 60802 at all. Thus, the reader is left out to figure it out from Table 9. Nevertheless, Table 9 is confusing. For instance, makes subclause 5.4 of IEEE Std 802.1Q mandatory in its second entry; but further entries claim some subclauses with 5.4.1 optional or even irrelevant.

Another example is that it is not clear in D1.0 whether or not time synchronization must be supported in all kinds of deployment, or is it optional as it only needs to be supported in some cases, therefore, it is overall optional; but certain aspects must be supported if conformance claim for synchronization support has been made. The difference between bridges and end stations is not clear in D1.0 with respect to what synchronization features must be supported and what are the optional features. Therefore, in this contribution, support for synchronization has been interpreted as an optional feature overall based on the rightmost column of Table 5 in D1.0. Thus, the conformance statements in this contribution try to capture based on D1.0 what is mandatory and what is optional if support for synchronization is claimed (which is optional overall). Note that if synchronization is mandatory overall, then the structure of synchronization conformance statements can be simplified.

The structure suggested in this contribution makes it very clear what a vendor needs to implement.

A bridge vendor claiming conformance to IEC/IEEE 60802:

- must implement subclauses 4.3.1, 4.3.2, 4.5.1, and 4.5.2 in all cases and must implement 4.3.3 and 4.5.3 if support for synchronization is claimed;
- may optionally implement subclauses 4.4 and 4.6.

An end station vendor claiming conformance to IEC/IEEE 60802:

- must implement subclauses 4.3.1, 4.3.2, and 4.7 in all cases and must implement 4.3.3 if support for synchronization is claimed;
- may optionally implement subclauses 4.4 and 4.8.

Furthermore, referencing from the PCS to the corresponding conformance is clear and unambiguous, see, e.g.,: BGE-1 to BGE-8, B-Q-1, or B-Q-2.

Note that the structure of Clause 4 may become simpler if different approach is taken for synchronization. This contribution is intended to illustrate the complex case. Note also that this contribution is just a fist attempt, further improvements are expected if this approach gets applied in the Draft.

Note also that this commenter suggests distinguishing whether an optional feature in a standard (or a complete standard) is irrelevant or an optional feature needs to be excluded. If an optional feature needs to be excluded or options should be specified further, then IEC/IEEE 60802 should provide the reference and specify what to do with it. This commenter considers unnecessary to mention standards or options that are irrelevant for IEC/IEEE 60802. Thus, statements introduced like “implementation for which a claim of conformance to support … is made does not need to support” and “implementation that conforms to the provisions of this standard does not need to” could be removed. (They are only there in this contributing to maintain the content of D1.0)

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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*

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

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

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

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

IEEE Std 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*

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

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

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

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

3 Terms, definitions, symbols and abbreviated terms

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1 TSN-IA defined Terms

3.1.1
TSN Domain
quantity of commonly managed industrial automation devices

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

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

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

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

3.3 Abbreviated terms and acronyms

Editor's Note: has to be updated before CDV stage!

IA	Industrial automation
TSN-IA	Time-Sensitive Networking for Industrial Automation

3.4 Conventions

3.4.1 Convention for Capitalizations

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

The following capitalized terms are used:

- Bridge
- Ethernet
- Internet
- Universal Time
- Working Clock

Parameter names are capitalized for example

- MinimumFrameMemory
- NetworkCycleTime
- NetworkCycle

– Phase
– ReductionRatio
– Sequence.

3.4.2 Unit conventions

This document uses

– Tbps for Tbit/s
– Gbps for Gbit/s and
– Mbps for Mbit/s.

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

4 Conformance

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

4.1 Requirements Terminology

Conformance requirements placed upon conformant implementations of this standard are expressed using the following terminology:

a) ***Shall*** is used for mandatory requirements;
b) ***May*** is used to describe implementation or administrative choices ("may" means "is permitted to," and hence, "may" and "may not" mean precisely the same thing);
c) ***Should*** is used for recommended choices (the behaviors described by "should" and "should not" are both permissible but not equally desirable choices).

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

The standard avoids needless repetition and apparent duplication of its formal requirements by using ***is***, ***is not***, ***are***, and ***are not*** for definitions and the logical consequences of conformant behavior. Behavior that is permitted but is neither always required nor directly controlled by an implementer or administrator, or whose conformance requirement is detailed elsewhere, is described by ***can***. Behavior that never occurs in a conformant implementation or system of conformant implementations is described by ***cannot***. The word ***allow*** is used as a replacement for the phrase "Support the ability for," and the word ***capability*** means "can be configured to."

4.2 Profile Conformance Statement (PCS)

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

4.3 Common requirements

This subclause defines the common conformance requirements that are applicable for both bridge and end station implementations claiming conformance to this standard.

4.3.1 Common TSN-IA Profile requirements

Bridge and end station implementations for which a claim of conformance to the TSN-IA Profile (Clause 6) is made, shall support

a) The common PHY and MAC requirements (4.3.2);
b) The common synchronization requirements (4.3.3);

c) The common management requirements (4.3.4);
d) IEEE Std 802.1AB-2016;
e) IEEE Std 802.1AC-2016.

4.3.2 Common PHY and MAC requirements

A bridge or end station implementation that conforms to the provisions of this standard shall support the following features as specified in IEEE Std 802.3-2018 or in its amendment:

a) Implement at least one full duplex IEEE Std 802.3-2018 MAC with data rate of 10 Mbps or greater together with the corresponding managed objects on each port, including 10 Mb/s Single Twisted Pair Ethernet specified in IEEE Std 802.3cg-20XX as a possibility;
b) Media Access Control (MAC) service specification (Clause 2 of IEEE Std 802.3-2018);
c) Media Access Control (MAC) frame and packet specifications (Clause 3 of IEEE Std 802.3-2018);
d) Each of the maximum MAC Client Data field sizes according (3.2.7 of IEEE 802.3-2018);
e) Media Access Control (Clause 4 of IEEE Std 802.3-2018);
f) Layer Management (Clause 5 of IEEE Std 802.3-2018);
g) Physical Signaling (PLS) service specifications (Clause 6 of IEEE Std 802.3-2018);
h) Physical Signaling (PLS) and Attachment Unit Interface (AUI) specifications (Clause 7 of IEEE Std 802.3-2018);
i) The capability not to assert Low Power Idle (LPI) on each port that supports Energy Efficient Ethernet (Clause 78 of IEEE Std 802.3-2018);
j) Ethernet support for time synchronization protocols (Clause 90 of IEEE Std 802.3-2018);
k) Interspersing Express Traffic (Clause 99 of IEEE Std 802.3-2018) for each MAC up to 1 Gbps;
l) The capability to disable MAC control PAUSE if it is implemented.

4.3.3 Common requirements for synchronization

A bridge or end station implementation for which a claim of conformance to support synchronization is made (see item b) in 4.4), shall support the following gPTP requirements (4.3.3.1) and meet the precision requirements (4.3.3.2).

4.3.3.1 gPTP requirements

A bridge or end station implementation that conforms to the provisions of this standard shall support the following features with the corresponding managed objects and PICS as specified in IEEE Std 802.AS-2019:

a) Time-aware system requirements (5.3 of IEEE Std 802.1AS-2019);
b) PTP Instance requirements (5.4 of IEEE Std 802.1AS-2019);
c) PTP Relay Instance requirements (5.4.2 of IEEE Std 802.1AS-2019);
d) MAC-specific timing and synchronization methods for IEEE 802.3 full-duplex links (5.6 of IEEE Std 802.1AS-2019).

4.3.3.2 Synchronization precision requirements

A bridge or end station implementation for which a claim of conformance to support synchronization is made (see item b) in 4.4) shall meet the following precision requirements:

The maximum link delay error shall be not greater than 10 ns;

Note – The maximum link delay error is externally measured from the MDI to MDI at the local link, including the asymmetry error contribution.

a) The Minimal timestamp accuracy for any kind of timestamp shall be not greater than
    1) 8 ns for a Working Clock;
    2) 8 ns for universal time.

4.3.4 Common management requirements

A bridge or end station implementation for which a claim of conformance to support SNMP MIBs is made shall support SNMP as specified in RFC 4789.

A bridge or end station implementation for which a claim of conformance to support SNMP MIBs is made shall support NETCONF as specified in RFC 6241.

4.4 Common options

This subclause defines options that are common for both bridge and end station implementations claiming conformance to this standard. A bridge or end station implementation that conforms to the provisions of this standard may support:

a) The common PHY and MAC options (4.4.1);
b) The common synchronization options (4.4.2);
c) The common management options (4.4.3);
d) The common security options (4.4.4);
e) IEEE Std 802.1CB-2017.

4.4.1 Common PHY and MAC options

A bridge or end station implementation that conforms to the provisions of this standard may support the following features as specified in IEEE Std 802.3-2018:

a) Interspersing Express Traffic (Clause 99 of IEEE Std 802.3-2018) for MAC greater than 1 Gbps;

4.4.2 Common synchronization options

A bridge or end station implementation that conforms to the provisions of this standard may support synchronization (4.3.3, 6.6).

A bridge or end station implementation for which a claim of conformance to support synchronization is made shall support the IEEE Std 802.1AS-2019 features listed in 4.3.3 and may support the following IEEE Std 802.1AS-2019 features:

a) Time-aware system options (5.4.1 of IEEE Std 802.1AS-2019);
b) MAC-specific timing and synchronization methods for IEEE Std 802.11 (5.6 of IEEE Std 802.1AS-2019);

<<**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.>>

A bridge or end station implementation for which a claim of conformance to support synchronization is made does not need to support the following IEEE Std 802.1AS-2019 features:

c) MAC-specific timing and synchronization methods for IEEE 802.3 EPON (5.7 of IEEE Std 802.1AS-2019);

d) MAC-specific timing and synchronization methods for coordinated shared network (CSN) (5.8 of IEEE Std 802.1AS-2019).

4.4.3 Common management options

A bridge or end station implementation that conforms to the provisions of this standard may support:

a) SNMP MIBs;

b) YANG.

4.4.4 Common security options

A bridge or end station implementation that conforms to the provisions of this standard may support the following standards for security:

a) MAC Security as specified by IEEE Std 802.1AE-2018 (6.7);

b) Port-Based Network Access Control as specified by IEEE Std 802.1X-2019 (6.7).

4.5 Bridge requirements

This subclause defines the conformance requirements that are applicable for bridge implementations claiming conformance to this standard.

4.5.1 Bridge TSN-IA Profile requirements

Bridge implementations for which a claim of conformance to the TSN-IA Profile (Clause 6) is made, shall support the common requirements (4.3), the bridging requirements (4.5.2), and the bridge requirements for synchronization (4.5.3).

4.5.2 Bridging requirements

A bridge implementation that conforms to the provisions of this standard shall:

a) Meet the VLAN Bridge requirements stated in items a) through r) in 5.4 of IEEE Std 802.1Q-2018;

b) Support Multiple Spanning Tree (MST) operation as stated in item a) in 5.4.1 and in 5.4.1.1 of IEEE Std 802.1Q-2018;

c) Support frame preemption as stated in item ad) in 5.4.1.1 of IEEE Std 802.1Q-2018;

d) Meet the Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS) requirements as stated in 5.4.1.5 of IEEE Std 802.1Q-2018;

e) Meet the C-VLAN component requirements stated in items a) through e) in 5.5 of IEEE Std 802.1Q-2018;

f) Meet the C-VLAN Bridge requirements stated in the introductory text in 5.9 of IEEE Std 802.1Q-2018;

g) Meet the MAC Bridge component requirements stated in items a) through j) in 5.13 of IEEE Std 802.1Q-2018;

h) Meet the MAC Bridge requirements stated in the introductory text in 5.14 of IEEE Std 802.1Q-2018;

i) Meet the MAC-specific bridging methods requirements stated in the introductory text in 5.22 of IEEE Std 802.1Q-2018;

j) Support the strict priority algorithm for transmission selection (8.6.8.1 in IEEE Std 802.1Q-2018) on each port for each traffic class;

k) Support at least eight traffic classes on each port;

l) Support at least five VLANs;

m) Support flow metering as specified in 8.6.5 in IEEE Std 802.1Q-2018;

n) Support priority regeneration as specified 6.9.4 in IEEE Std 802.1Q-2018;

o) Support the capability to disable Priority-based flow control if it is implemented (Clause 36 of IEEE Std 802.1Q-2018).

<<**Editor’s note**: insert reference to appropriate section once “FDB and resource requirements” discussion is concluded.>>

4.5.3 Bridge requirements for synchronization

A bridge implementation for which a claim of conformance to support synchronization is made (see item 0 in 4.4), shall support the gPTP requirements (4.3.3.1) and meet the precision requirements (4.3.3.2) and the following precision requirement:

a) The maximum residence time error contribution of a bridge shall be not greater than 10 ns.

Note – The maximum link delay error is externally measured from the MDI to MDI at the bridge.

4.6 Bridge options

A bridge implementation that conforms to the provisions of this standard may:

a) Meet the VLAN Bridge options stated in items b) through ac) in 5.4.1 of IEEE Std 802.1Q-2018;

b) Support Multiple MAC Registration Protocol (MMRP) operation as stated in 5.4.1.3 of IEEE Std 802.1Q-2018;

c) Meet the Per-stream filtering and policing (PSFP) requirements as stated in 5.4.1.8 of IEEE Std 802.1Q-2018;

d) Meet the Cyclic queuing and forwarding (CQF) requirements as stated in 5.4.1.9 of IEEE Std 802.1Q-2018;

e) Meet the Multiple VLAN Registration Protocol (MVRP) requirements as stated in 5.4.2 of IEEE Std 802.1Q-2018;

f) Meet the Multiple Stream Registration Protocol (MSRP) requirements stated in 5.4.4 of IEEE Std 802.1Q-2018;

g) Meet the C-VLAN component options stated in 5.5.1 of IEEE Std 802.1Q-2018;

h) Meet the C-VLAN Bridge options stated in 5.9.1 of IEEE Std 802.1Q-2018;

i) Meet the MAC Bridge component options stated in 5.13.1 of IEEE Std 802.1Q-2018;

j) Meet the MAC Bridge options stated in 5.14.1 of IEEE Std 802.1Q-2018;

k) Meet the bridge requirements specified by IEEE Std 802.1Qcc-2018;

l) Meet the bridge requirements specified by IEEE Std 802.1Qcp-2018.

A bridge implementation that conforms to the provisions of this standard does not need to:

m) Support Port-and-Protocol-based VLAN classification stated in 5.4.1.2 of IEEE Std 802.1Q-2018;
n) Support Connectivity Fault Management (CFM) stated in 5.4.1.4 of IEEE Std 802.1Q-2018;
o) Meet the ETS Bridge requirements stated in 5.4.1.6 of IEEE Std 802.1Q-2018;
p) Meet the DCBX Bridge requirements stated in 5.4.1.7 of IEEE Std 802.1Q-2018;
q) Meet the VLAN Bridge requirements for congestion notification stated in 5.4.3 of IEEE Std 802.1Q-2018;
r) Support Shortest Path Bridging (SPB) operation stated in 5.4.5 of IEEE Std 802.1Q-2018;
s) Support Path Control and Reservation (PCR) operation stated in 5.4.5 of IEEE Std 802.1Q-2018;
t) Meet the S-VLAN component requirements stated in 5.6 of IEEE Std 802.1Q-2018;
u) Meet the I-component requirements stated in 5.7 of IEEE Std 802.1Q-2018;
v) Meet the B-component requirements stated in 5.8 of IEEE Std 802.1Q-2018;
w) Meet the Provider Bridge requirements stated in 5.10 of IEEE Std 802.1Q-2018;
x) Meet the System requirements for Priority-based Flow Control (PFC) requirements stated in 5.11 of IEEE Std 802.1Q-2018;
y) Meet the Backbone Edge Bridge (BEB) requirements stated in 5.12 of IEEE Std 802.1Q-2018;
z) Meet the TPMR component requirements stated in 5.15 of IEEE Std 802.1Q-2018;
aa) Meet the TPMR requirements stated in 5.16 of IEEE Std 802.1Q-2018;
bb) Meet the T-component requirements stated in 5.17 of IEEE Std 802.1Q-2018;
cc) Meet the EVB Bridge requirements stated in 5.23 of IEEE Std 802.1Q-2018.

4.7 End station requirements

This subclause defines the conformance requirements that are applicable for end station implementations claiming conformance to this standard.

4.7.1 End station TSN-IA Profile requirements

Bridge implementations for which a claim of conformance to the TSN-IA Profile (Clause 6) is made, shall support the common requirements (4.3).

4.8 End station options

A bridge implementation that conforms to the provisions of this standard may:

a) Meet the end station requirements and options for MMRP, MVRP, and MSRP stated in 5.18 of IEEE Std 802.1Q-2018;
b) Meet the end station requirements for FQTSS as stated in 5.20 of IEEE Std 802.1Q-2018;
c) Meet the end station requirements for enhancements for scheduled traffic as stated in 5.25 of IEEE Std 802.1Q-2018;
d) Meet the end station requirements for enhancements for frame preemption as stated in 5.26 of IEEE Std 802.1Q-2018;
e) Meet the end station requirements for PSFP as stated in 5.27 of IEEE Std 802.1Q-2018;
f) Meet the end station requirements for cyclic queuing and forwarding as stated in 5.28 of IEEE Std 802.1Q-2018;
g) Meet the end station requirements specified by IEEE Std 802.1Qcc-2018.

A bridge implementation that conforms to the provisions of this standard does not need to:

h) Support Port-and-Protocol-based VLAN classification stated in 5.4.1.2 of IEEE Std 802.1Q-2018;

i) Meet the End station requirements for congestion notification stated in 5.21 of IEEE Std 802.1Q-2018;

j) Meet the EVB station requirements stated in 5.24 of IEEE Std 802.1Q-2018.

5 Industrial Automation

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

5.1 Overview

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

5.1.1 Control Loop Basic Model

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

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

Error! Reference source not found. shows the whole transmission path from Controller application to Device application(s) and back. The blue and red arrows show the contributions to the e2e (end-to-end) latency respectively.

Error! Reference source not found. and **Error! Reference source not found.** show three levels of a control loop:

- Application - within End Station,
- Network Access - within End Station,
- Network / Bridges - within Bridges.

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

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

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

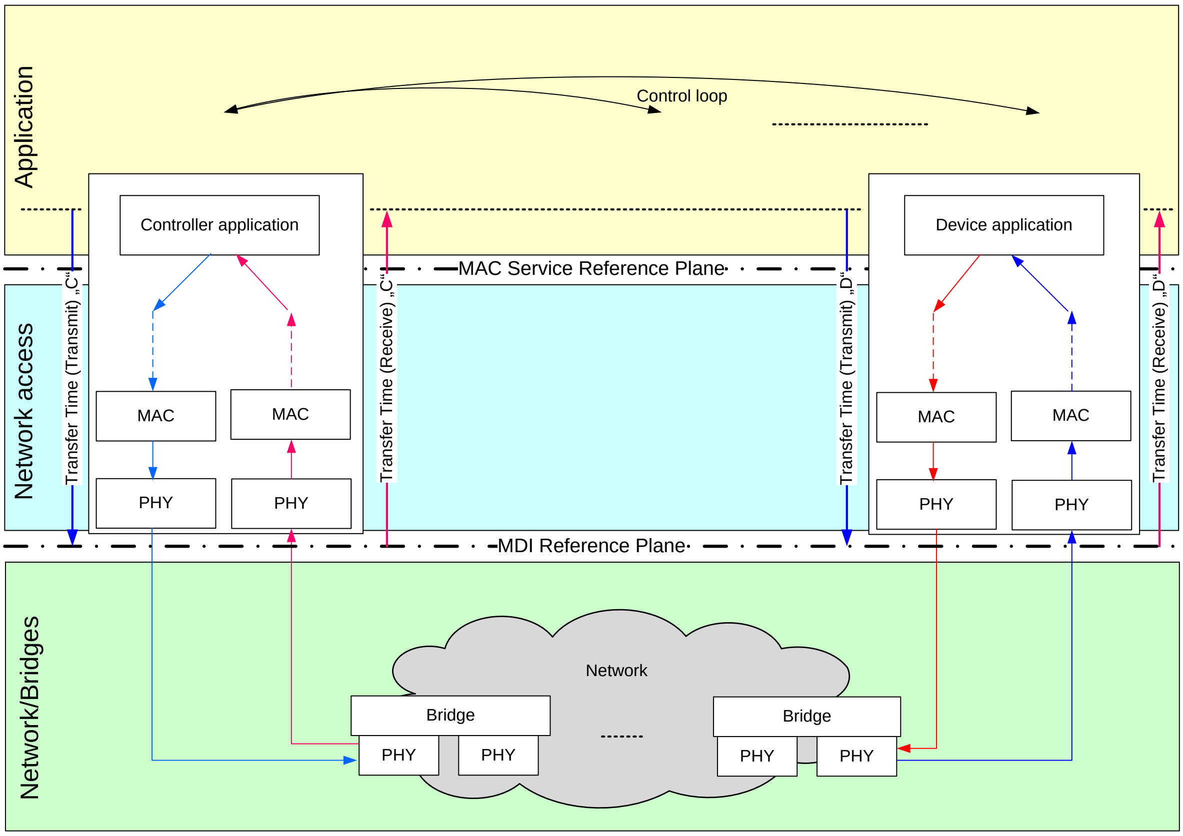

Figure 1 – Principle data flow of control loop

Transfer Times contain PHY and MAC delays. Both delays are asymmetric and vendor specific. Device vendors have to take into account these transfer times when their application cycle models are designed (see **Error! Reference source not found.**).

Table 2 – 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

5.1.2 Industrial Traffic Types

Industrial automation applications concurrently make use of different traffic schemes/patterns for different functionalities, e.g. parameterization, control, alarming. The various traffic patterns have different characteristics and thus impose different requirements on a TSN network.

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

Table 3 – 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

5.2 Requirements

This subclause summarizes Industrial Automation requirements to bridged networks.

5.2.1 Bridge delay requirements

Figure 2 shows the definition the Bridge delay reference points. To make short control loop times feasible Bridge-delays shall be independent from the frame size and meet the upper limits of Table 4.

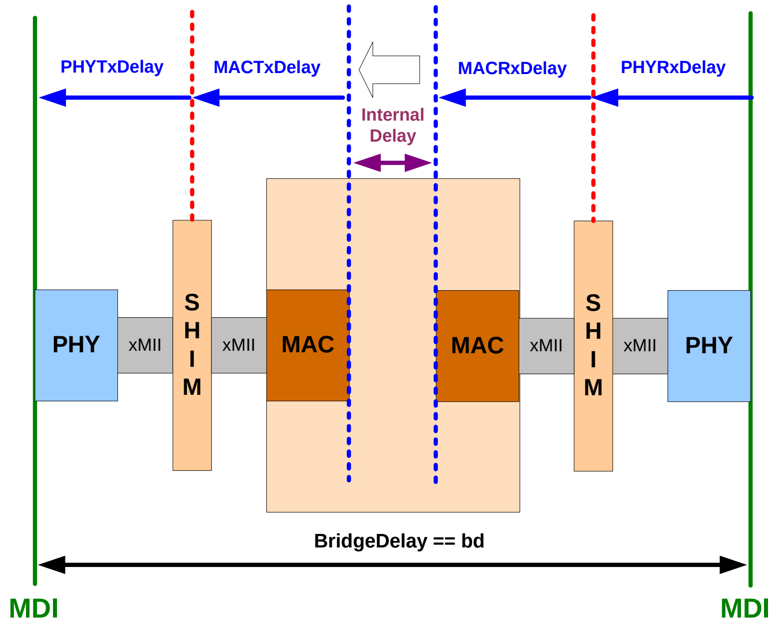

Figure 2 – Delay measurement reference points

Table 4 – Required Ethernet Bridge delays

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

5.2.2 Network access

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

a) Synchronization to working clock;

b) Stream class based scheduling with:

- o Network cycle,
  - < 50 % bandwidth per link for < 1 Gbps for streams;
  - < 20 % bandwidth per link for >= 1 Gbps for streams;
  - < 25 % bandwidth per link for non-streams;
- o Reduction ratio;
- o Phase;
- o Sequence;

- o Transmit of frames as a convoy starts at network cycle start with minimum interpacket gap (IPG); first isochronous cyclic real-time frames, second cyclic real-time frames, third non-stream frames;
- o Reception of frames before assigned network cycle based deadline;

c) Time limits for transfer time (receive), see **Error! Reference source not found.**, shall be <= 3 µs in addition to PHY-delay and MAC-delay;

d) Time limits for transfer time (transmit), see **Error! Reference source not found.**, shall be <= 3 µs in addition to PHY-delay and MAC-delay;

e) Network access parameters:

- o NetworkCycle according to Table 5,
- o ReductionRatio according to Formula (1),
- o Phase according to Formula (2),
- o Sequence according to Formula (3).

Table 5 – 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.

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

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

Where

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

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

Step 1 & 2

PhaseNumber = 1 to ReductionRatio (2)

Where

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

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

5.2.3 Bridge FDB requirements

Editor's note: Contribution requested.

5.2.4 Bridge resource requirements

Editor's note: Contribution requested.

5.2.5 Quantities

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

k) Stations: >= 1 024

l) Network diameter: >= 64

m) Streams per PLC for Controller-to-Device (C2D) communication:
   - >= 512 talker and >= 512 listener streams;
   - >= 1 024 talker and >= 1 024 listener streams in case of seamless redundancy;

n) Streams per PLC for Controller-to-Controller (C2C) communication:
   - >= 64 talker and >= 64 listener streams;
   - >= 128 talker and >= 128 listener streams in case of seamless redundancy.

o) Streams per Device for Device-to-Device (D2D) communication:
   - >= 2 talker and >= 2 listener streams;
   - >= 4 talker and >= 4 listener streams in case of seamless redundancy.

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

- o 8 x 512 x 2 = 8 192 streams for C2D communication, plus
- o 8 x 64 x 2 = 1 024 streams for C2C communication
- o (8 192 + 1 024) * 2 000 = 18 432 000 Bytes data of all streams

5.2.6 Synchronization requirements

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

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

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

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

5.2.6.1 Universal Time synchronization

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

5.2.6.2 Working Clock synchronization

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

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

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

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

5.2.6.3 General Requirements for Synchronization

Synchronization domain settings shall be according to **Error! Reference source not found.** and **Error! Reference source not found.**.

Table 6 – 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.

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

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

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

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

All members of a synchronization domain may take at least one of the roles specified in **Error! Reference source not found.**.

Table 7 – 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

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

The requirements concerning the overall maximum deviation to the grandmaster time in the synchronization domains in **Error! Reference source not found.** shall be fulfilled.

Table 8 – Maximum deviation to grandmaster time requirements

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

Editor's Note: reference number of hops (100) – "grandmaster time" must be defined – from TAI in case of universal time

Error! Reference source not found. shows the number of hops which shall be supported.

Table 9 – 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.

The maximum working clock deviation between two devices, which are synchronized to the same grandmaster, shall be < 2 µs when the working clock requirement of **Error! Reference source not found.** is observed.

<<**Contributor's note**:

Not sure about good location. Table 15 and Table 16 are device requirements. Sections 4.3.3.2 and 4.5.3 of this contribution show an attempt how Table 15 and Table 16 may look like if converted to conformance requirement, i.e., if a device claiming conformance to this standard must meet the requirement. Note that, in this contribution, support for synchronization has been interpreted as an optional feature based on the rightmost column of Table 5 in D1.0.>>

The maximum error contribution of every single network node of the domains shall be according to **Error! Reference source not found.**.

Table 10 – 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.

Minimal timestamp accuracy for any kind of timestamp shall be according to **Error! Reference source not found.**.

Table 11 – Timestamp accuracy

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

Error! Reference source not found. specifies the clock synchronization profile contribution. The selection of the different clock types per device shall be provided using PICS.

Editor's Note: add requirement about asymmetry compensation

6 Industrial Automation profile

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

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

6.1 Frame size

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

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

6.2 Traffic classes

6.3 Latency

6.4 Frame loss

6.5 VLANs

6.6 Synchronization

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

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

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

All members of a synchronization domain may take at least one of the roles specified in **Error! Reference source not found.**.

Table 12 – 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

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

6.7 Security

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

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

6.8 Further considerations

<<**Contributor’s note**:

Further considerations can be added here. A couple of examples provided in this contribution.

>>

6.8.1 Frame preemption

6.8.2 Flow control

The operation of flow control protocols, for example MAC control PAUSE (IEEE Std 802.3), or Priority-based flow control (IEEE Std 802.1Q) operating on the priorities that are used to support industrial automation traffic, can invalidate latency guarantees for industrial automation traffic. Therefore, a bridge of an industrial automation bridged network shall be configurable to disable MAC control PAUSE. MAC control PAUSE is disabled on any ports that support industrial automation traffic. A bridge of an industrial automation bridged network shall be configurable to disable Priority-based flow control. Priority-based flow control is disabled for the priorities associated with industrial automation traffic on any ports that support industrial automation traffic.

Given the bridge architectural model for points of attachment for higher layer entities, as illustrated in Figure 8-18 of IEEE Std 802.1Q-2018, no higher layer entities within a bridge are subject to these restrictions on the use of flow control protocols. However, where the implementation makes use of the same MAC interface to support relayed frames and also higher layer protocol operation, and where the implementation supports other MAC control protocols that are not subject to relay by the bridge, all transmitted frames that are not relayed by the bridge are subject to the same transmission selection algorithms as relayed frames, in order to ensure that latency is not adversely affected.

6.8.3 Energy Efficient Ethernet

Energy Efficient Ethernet (EEE, specified in IEEE Std 802.3) specifies a Low Power Idle (LPI) mode of operation for Ethernet LANs that allows the LAN to transition to a low power state when there is no activity. Control of the LPI state is performed by the LPI client, which determines, on the transmission side, when LPI is asserted and when it is de-asserted. When LPI is de-asserted, there is a delay (wake time) before the link is ready to operate; the longer the wake time, the longer the additional latency due to the operation of EEE. Therefore, in an industrial automation bridged network, bridges do not assert LPI on a port that supports EEE and industrial automation traffic.

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

A.3 Instructions for completing the PCS proforma

A.3.1 General structure of the PCS proforma

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

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

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

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

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

A.3.2 Additional information

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

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

A.3.3 Exception Information

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

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

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

A.3.4 Conditional status

A.3.4.1 Conditional items

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

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

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

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

A.3.4.2 Predicates

A predicate is one of the following:

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

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

A.3.4.3 References to other standards

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

<standard abbreviation>:<clause-number>

where standard abbreviation is one of the following:

Q: IEEE Std 802.1Q

AS: P802.1AS-REV

Dot3: IEEE Std 802.3

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

A.4 Common requirements

A.4.1 Implementation identification

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

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	

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

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

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. Amd.	: :	Corr. 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				

A.4.3 Implementation type

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

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 [ ]

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

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	Dot3, a)	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 [ ]

A.4.5 Common requirements— Bridges

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

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

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

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

A.4.6 Major capabilities—Bridges

Item	Feature	Status	References	Support	
BGE-1	Do all ports support a maximum frame size of 2000 octets?	M	Dot3, 4.3.2: d)	Yes [ ]	No [ ]
BGE-2	Does the Bridge support disabling of priority-based flow control?	M	4.5.2: o)	Yes [ ]	No [ ]
BGE-3	Does the Bridge support disabling MAC control PAUSE if implemented?	M	4.3.2: l)	Yes [ ]	No [ ]
BGE-4	Does the Bridge support disabling of Energy Efficient Ethernet?	M	4.3.2: i)	Yes [ ]	No [ ]

BGE-5	Does the Bridge support the strict priority algorithm on each port?	M	4.5.2: j)	Yes [ ]	No [ ]
BGE-6	Does the Bridge support 8 queues on each port?	M	4.5.2: k)	Yes [ ]	No [ ]
BGE-7	Does the Bridge support priority regeneration?	M	4.5.2: n)	Yes [ ]	No [ ]
BGE-8	Does the Bridge support preemption?	M	4.3.2: k)	Yes [ ]	No [ ]
BGE-9	Does the Bridge meet the bridge delays specified in 5.2.1?	M	Table 4	Yes [ ]	No [ ]

A.4.7 IEEE Std 802.1Q requirements—Bridges

Item	Feature	Status	References	Support	
B-Q-1	Does the bridge support VLAN Bridge component requirements a) through r)**Error! Reference source not found.**?	M	**Q:5.4, 4.5.2: a)Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-2	Does the bridge support requirements for VLAN Bridge per IEEE802.1Q 5.4.1 and **Error! Reference source not found.**?	O	**4.6: a) Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-3	Does the Bridge support MSTP **Error! Reference source not found.**?	M	**Q:5.4.1 a), Q:5.4.1.1, 4.5.2: b)Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-4	Does the bridge support MMRP **Error! Reference source not found.**?	O	**Q:5.4.1.3, 4.6: b)Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-5	State the number of Ports supporting Enhancements for scheduled traffic per IEEE802.1Q 5.4.1 and **Error! Reference source not found.**	O	**Error! Reference source not found.**	Number_____	
B-Q-6	State the number of Ports supporting FQTSS per IEEE802.1Q 5.4.1.5 and **Error! Reference source not found.**	O	**Error! Reference source not found.**	Number_____	
B-Q-7	State the number of Ports supporting PSFP per IEEE802.1Q 5.4.1.8 and **Error! Reference source not found.**	O	**Error! Reference source not found.**	Number_____	
B-Q-8	State the number of Ports supporting CQF per IEEE802.1Q 5.4.1.9 and **Error! Reference source not found.**	O	**Error! Reference source not found.**	Number_____	
B-Q-9	Does the Bridge support MVRP per IEEE802.1Q 5.4.2 and Table 10?	O	**Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-10	Does the Bridge support MSRP per IEEE802.1Q 5.4.4 and **Error! Reference source not found.**?	O	Error! Reference source not found.**Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-11	Does the Bridge support C-VLAN requirements per IEEE802.1Q 5.5, 5.9 and **Error! Reference source not found.**?	O	Error! Reference source not found.**Error! Reference source not found.**	Yes [ ]	No [ ]
B-Q-12	Does the Bridge support MAC Bridge component requirements per IEEE802.1Q 5.13, 5.14 and **Error! Reference source not found.**?	O	Error! Reference source not found.**Error! Reference source not found.**	Yes [ ]	No [ ]

B-Q-13	State the number of Asynchronous Traffic Shaping per IEEE P802.1Qcr D0.0 and **Error! Reference source not found.**	O	**Error! Reference source not found.**	Number_____	
B-Q-14	Does the Bridge support IEEE802.1Qcc-2018 per **Error! Reference source not found.**?	O	Error! Reference source not found.	Yes [ ]	No [ ]
B-Q-15	Does the Bridge support IEEE P802.1Qdd per Table 10?	O	Error! Reference source not found.	Yes [ ]	No [ ]

A.4.8 Time Synchronization Requirements

Item	Feature	Status	References	Support	
TS-1	Does the implementation support four domains as specified in **Error! Reference source not found.**?	M	**Error! Reference source not found.**	Yes [ ]	No [ ]
TS-2	Does the implementation comply with the maximum error contribution per network node specified in **Error! Reference source not found.**?	M	**Error! Reference source not found.**	Yes [ ]	No [ ]
TS-3	Does the implementation comply with the timestamp accuracy specified in **Error! Reference source not found.**?	M	**Error! Reference source not found.**	Yes [ ]	No [ ]
TS-4	Does the implementation comply with Time aware system requirements specified in AS: 5.3 and **Error! Reference source not found.**?	M	AS:5.3, **Error! Reference source not found.**	Yes [ ]	No [ ]
TS-5	Does the implementation comply with PTP instance requirements specified in AS: 5.4 and **Error! Reference source not found.**?	M	AS:5.4, **Error! Reference source not found.**	Yes [ ]	No [ ]
TS-5	Does the implementation comply with PTP instance requirements specified in AS: 5.4 and **Error! Reference source not found.**?	M	AS:5.4, **Error! Reference source not found.**	Yes [ ]	No [ ]
TS-6	List the number of ports supporting the media-independent master capability	O	AS:5.4.1, **Error! Reference source not found.**	Number_____	
TS-7	Is the implementation Grand Master capable as specified in AS: 5.4.1 and **Error! Reference source not found.**?	O	AS:5.4.1, **Error! Reference source not found.**	Yes [ ]	No [ ]
TS-8	List the number of ports supporting PTP Relay Instance capability	O	AS:5.4.2, **Error! Reference source not found.**	Number_____	
TS-9	Does the implementation support media-independent attributes of the Announce message and the Signaling message	O	AS:5.4.1, **Error! Reference source not found.**	Yes [ ]	No [ ]
TS-10	Does the implementation support the SyncIntervalSetting state machine	O	AS:5.4.1, **Error! Reference source not found.**	Yes [ ]	No [ ]
TS-11	Does the implementation support timing and synchronization management	M	AS:5.4.1, **Error! Reference source not found.**	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, **Error! Reference source not found.**	Number_____
TS-13	List the number of ports supporting MAC-specific timing and synchronization methods for IEEE 802.11	O	AS:5.6, **Error! Reference source not found.**	Number_____

A.4.9 Security Requirements

Item	Feature	Status	References	Support	
SEC-1	Does the implementation support IEEE 802.1AE™- 2006?	O	**Error! Reference source not found.**	Yes [ ]	No [ ]
SEC-2	Does the implementation support IEEE 802.1AEbn™- 2011?	Dot1AE:M	**Error! Reference source not found.**	Yes [ ]	No [ ]
SEC-3	Does the implementation support IEEE 802.1AEbw™- 2013?	Dot1AE:M	**Error! Reference source not found.**	Yes [ ]	No [ ]
SEC-4	Does the implementation support IEEE 802.1AEcg?	Dot1AE:M	**Error! Reference source not found.**	Yes [ ]	No [ ]
SEC-5	Does the implementation support IEEE 802.1AR™- 2009?	Dot1AE:M	**Error! Reference source not found.**	Yes [ ]	No [ ]
SEC-6	Does the implementation support IEEE 802.1X™- 2009?	O	**Error! Reference source not found.**	Yes [ ]	No [ ]
SEC-6	Does the implementation support IEEE 802.1Xbx™- 2014?	O	**Error! Reference source not found.**	Yes [ ]	No [ ]

Annex Z

(informative/normative)

Gaps

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

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

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

Bibliography

IEEE Std 1588™-2008, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*