IEEE P802.1DP/D2.0

Draft Standard for
Local and metropolitan area networks—

Time-Sensitive Networking for Aerospace Onboard Ethernet Communications

Unapproved draft, prepared by the
Time-Sensitive Networking (TSN) Task Group of IEEE 802.1

Sponsored by the
LAN/MAN Standards Committee
of the
IEEE Computer Society

This and the following cover pages are not part of the draft. They provide revision and other information for IEEE 802.1 Working Group members and participants in the IEEE Standards Association ballot process, and will be updated as convenient. New participants: Please read these cover pages, they contain information that should help you contribute effectively to this standards development project. Blank pages allow for the addition of cross-references to changed text without forcing renumbering of all pages in the draft. Pages are numbered from 1 (including cover pages) for the convenience of reviewers whose PDF viewers do not easily accommodate different numbering sequences. Pages will of course be renumbered prior to publication.

The text proper of this draft begins with the Title page.

Editors' Foreword

This draft is prepared for the first working group ballot.

Participation in 802.1 standards development

All participants in the standardization activities of IEEE 802.1 should be aware of the Working Group Policies and Procedures, and the fact that they have obligations under the IEEE Patent Policy, the IEEE Standards Association (SA) Copyright Policy, and the IEEE SA Participation Policy. For information on these policies see 1.ieee802.org/rules/ and the slides presented at the beginning of each of our Working Group and Task Group meeting.

As part of our IEEE 802® process, the text of the PAR (Project Authorization Request) and CSD (Criteria for Standards Development) of each project is reviewed regularly to ensure their continued validity. The PAR is summarized in these cover pages and a links are provided to the full text of both PAR and CSD. A vote of "Approve" on this draft is also an affirmation that the PAR and CSD for this project are still valid.

Comments on this draft are encouraged. NOTE: All issues related to IEEE standards presentation style, formatting, spelling, etc. are routinely handled between the 802.1 Editor and the IEEE Staff Editors prior to publication, after balloting and the process of achieving agreement on the technical content of the standard is complete. Readers are urged to devote their valuable time and energy only to comments that materially affect either the technical content of the document or the clarity of that technical content. Comments should not simply state what is wrong, but also what might be done to fix the problem.

Full participation in the work of IEEE 802.1 requires attendance at IEEE 802 meetings. Information on 802.1 activities, working papers, and email distribution lists etc. can be found on the 802.1 Website:

http://ieee802.org/1/

Use of the email distribution list is not presently restricted to 802.1 members, and the working group has a policy of considering comments from all who are interested and willing to contribute to the development of the draft. Individuals not attending meetings have helped to identify sources of misunderstanding and ambiguity in past projects. The email lists exist primarily to allow the members of the working group to develop standards, and are not a general forum. All contributors to the work of 802.1 should familiarize themselves with the IEEE patent policy and anyone using the email distribution list will be assumed to have done so. Information can be found at http://standards.ieee.org/db/patents/

Comments on this draft may be sent to the 802.1 email exploder, to the Editor, or to the Chairs of the 802.1 Working Group and Time-Sensitive Networking (TSN) Task Group.

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NOTE: Comments whose distribution is restricted in any way cannot be considered, and may not be acknowledged.

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As part of our IEEE 802 process, the text of the PAR and CSD (Criteria for Standards Development, formerly referred to as the 5 Criteria or 5C's) is reviewed on a regular basis in order to ensure their continued validity. A vote of "Approve" on this draft is also an affirmation by the balloter that the PAR is still valid.

Draft development

During the early stages of draft development, 802.1 editors have a responsibility to attempt to craft technically coherent drafts from the resolutions of ballot comments and from the other discussions that take place in the working group meetings. Preparation of drafts often exposes inconsistencies in editor's instructions or exposes the need to make choices between approaches that were not fully apparent in the meeting. Choices and requests by the editors' for contributions on specific issues will be found in the editors' Introduction to the current draft and at appropriate points in the draft.

The ballot comments received on each draft, and the editors' proposed and final disposition of comments on working group drafts, are part of the audit trail of the development of the standard and are available, along with all the revisions of the draft on the 802.1 website (for address see above).

During the early stages of draft development the proposed text can be moved around a great deal, and even minor rearrangement can lead to a lot of 'change', not all of which is noteworthy from the point of the reviewer, so the use of automatic change bars is not very effective. In early drafts change bars may be omitted or applied manually, with a view to drawing the readers attention to the most significant areas of change. Readers interested in viewing every change are encouraged to use Adobe Acrobat to compare the document with their selected prior draft. Note that the FrameMaker change bar feature is useless when it comes to indicating changes to Figures.

iPAR (Project Authorization Request) and CSD

Extracts from the PAR, as approved by IEEE NesCom 3rd December 2020:

https://development.standards.ieee.org/myproject-web/public/view.html#pardetail/8705

and the CSD (Criteria for Standards Development):

https://mentor.ieee.org/802-ec/dcn/21/ec-21-0096-00-ACSD-p802-1dp.pdf

follow.

This is a joint development with:

SAE Avionics Networks AS-1 A2 IEEE and SAE Joint Development Procedure.[1]

PAR Scope:

This standard specifies profiles of IEEE 802.1 Time-Sensitive Networking (TSN) and IEEE 802.1 Security standards for aerospace onboard bridged IEEE 802.3 Ethernet networks. The profiles select features, options, configurations, defaults, protocols, and procedures of bridges, end stations, and Local Area Networks to build deterministic networks for aerospace onboard communications.

PAR Purpose:

This standard specifies profiles for designers, implementers, integrators, and certification agencies of deterministic IEEE 802.3 Ethernet networks that support a broad range of aerospace onboard applications including those requiring security, high availability and reliability, maintainability, and bounded latency.

PAR Need for the Project:

The aerospace segment does not have profiles of IEEE 802.1 TSN standards. The lack of standardized TSN profiles makes the definition of the aerospace manufacturers requirements and the implementation of those requirements by suppliers more difficult and costly. Thus, there is a need to standardize the selection and use of IEEE 802.1 and IEEE 802.3 standards and features in order to be able to deploy secure, highly-reliable converged networks, and enable certification as a basis for compliance and design assurance.

CSD managed objects [extract]

…managed object…definitions will not be developed…because this project will specify profiles that define the use and configuration of functions specified in other IEEE 802 standards, thus relying on the managed objects specified by the referred standards. [Partial extract from the CSD].

CSD broad market potential [extract]

IEEE 802.1 Time-Sensitive Networking (TSN) gives an opportunity to unify networking for aerospace onboard Ethernet communications. TSN is the foundation to provide interoperability and connectivity for aerospace applications on converged networks to support traffic that has high-reliability and deterministic latency requirements. However, the breadth of choices in the use of the TSN features inhibits the interoperability of products designed for a particular market. By narrowing the focus, this profile expands the market for bridges, end stations, network interface cards, and integrated circuits. The specification and use of TSN features in these scenarios via TSN profiles is beneficial for suppliers offering and/or developing TSN products, e.g., in order to ease interoperability and deployment.

Many aerospace manufacturers, suppliers, and customers consider TSN as the next generation networking technology enabler to meet the deterministic latency, security, and high reliability requirements of aerospace onboard networks. The TSN profiles for aerospace are essential for them.

CSD compatibility [extract]

The project will comply with IEEE Std 802, IEEE Std 802.1AC, and IEEE Std 802.1Q.

[1]https://www.ieee802.org/1/files/private/dp-drafts/IEEE-SAE_Joint_Dev_Procedure-TSN_Aerospace_Profile.pdf

Introduction to the current draft

This introduction is not part of the draft, and will be revised for SA ballot. A set of cover pages will be retained for use during SA ballot.

This draft (2.0) of P802.1DP was created for the first working group ballot. Both technical and editorial comments are welcome. Reviewers are encouraged to provide “suggested remedy” when providing a comment. This draft addresses the comments from previous task group ballots according to the comment disposition document.

P802.1DP/Draft 2.0
May 6, 2024

IEEE P802.1DP/D2.0

Draft Standard for Local and metropolitan area networks—

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Abstract: This standard specifies a profiles of IEEE 802.1 Time-Sensitive Networking (TSN) for aerospace onboard bridged IEEE 802.3 Ethernet networks. The profile selects features, options, configurations, defaults, protocols, and procedures of bridges, end stations, and Local Area Networks to build deterministic networks for aerospace onboard communications.

Keywords: Bridged Network, IEEE 802.1Q™, LAN, local area network, MAC security, MACsec, privacy, Virtual Bridged Network, virtual LAN, VLAN Bridge

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1. Available at: https://development.standards.ieee.org/myproject-web/public/view.html#landing.
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3. Available at: https://ieeexplore.ieee.org/browse/standards/collection/ieee.
4. Available at: https://standards.ieee.org/standard/index.html.
5. Available at: https://standards.ieee.org/about/sasb/patcom/materials.html.

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Participants

<<The following lists will be updated in the usual way prior to publication>>

At the time this standard was completed, the IEEE 802.1 working group had the following membership:

Glenn Parsons, *Chair*
Jessy Rouyer, *Vice Chair*
Janos Farkas, *Security Task Group Chair*
Abdul Jabbar, *Editor*

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

A.N. Other

<<The above lists will be updated in the usual way prior to publication>>

When the IEEE-SA Standards Board approved this standard on <dd> <month> <year>, it had the following membership:

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*Member Emeritus

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Introduction

This introduction is not part of IEEE Std 802.1DP-20XX, IEEE Standard for Local and metropolitan area networks—Time-Sensitive Networking for Aerospace Onboard Ethernet Communications

This standard specifies profiles of IEEE 802.1 Time-Sensitive Networking (TSN) and IEEE 802.1 Security standards for aerospace onboard bridged IEEE 802.3 Ethernet networks.

This standard was first published as IEEE Std 802.1DP-20XX.

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision state of this and other IEEE 802 standards may be obtained from

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USA

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Draft Standard for Local and Metropolitan Networks —

Time-Sensitive Networking for Aerospace Onboard Ethernet Communications

1. Overview

The standardization of Ethernet communication technology in IEEE Std 802.3™, specifying transmission over the physical media of individual Local Area Networks (LANs), and in IEEE Std 802.1Q™, specifying Bridges that interconnect IEEE 802® LANs,[1] has facilitated widespread deployment of networks that connect significantly more end stations, with significantly greater bandwidth, and at significantly reduced cost compared to prior technology. All these metrics have been improved by several orders of magnitude—reducing costs through the multi-vendor provision of common components (bridges, end station interfaces, integrated circuit and circuit designs, connectors, and software) for a wide range of network applications.

The use of Ethernet communication technology in networks with high-reliability and deterministic latency requirements is further supported by Time-Sensitive Networking (TSN) provisions in IEEE Std 802.1Q, IEEE Std 802.1AS, IEEE Std 802.1CB, and the security provisions in IEEE Std 802.1AE and IEEE Std 802.1X. The provisions in these standards can be used in various ways, and include options that address different network requirements and parameters that vary by network and application scale. Network design, time to deploy, and component development, selection, validation, and configuration for a particular network can all benefit from consistent choices, across similar networks and network applications, of the provisions, parameters, and options specified in the relevant standards. A set of such choices comprises a *profile* of those standards and target networks.

This standard is a profile for use in Ethernet networks supporting aerospace onboard communications. These networks and their network components have stringent verification requirements, so the profile emphasizes not just what capabilities are to be available and how they are used, but also what optional capabilities are not used. All available capabilities can be subject to time-consuming and expensive verification, so omission of unused capabilities is desirable and can be required.

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1.1 Scope

This standard specifies profiles of IEEE 802.1 Time-Sensitive Networking (TSN) and IEEE 802.1 Security standards for aerospace onboard bridged IEEE 802.3 Ethernet networks. The profiles select features, options, configurations, defaults, protocols, and procedures of bridges, end stations, and Local Area Networks to build deterministic networks for aerospace onboard communications.

1.2 Purpose

This standard specifies profiles for designers, implementers, integrators, and certification agencies of deterministic IEEE 802.3 Ethernet networks that support a broad range of aerospace onboard applications including those requiring security, high availability and reliability, maintainability, and bounded latency.

1.3 Introduction

The TSN suite of standards are broad ranging, and intended for use in a variety of environments that require bounded latency, synchronization, reliability, isolation, and high availability. This standard selects the TSN features that are directly applicable to Aerospace Onboard Ethernet Communications and explains how the associated TSN standards are used. This standard narrows the focus from the broad set of available TSN features to those that are applicable to aerospace onboard networks.

The profile describes aerospace use cases and associated functional requirements to explain how TSN is expected to be used in aerospace platforms. The conformance clause, Clause 5, specifies mandatory and optional features that are expected to be provided by conformant implementations of systems, system components, and system functions used in aerospace onboard Ethernet networks.

Aerospace OEMs and suppliers at all tiers should be able to use this standard to specify and design the network and network components required to implement the systems and functions required by aerospace platforms. Component and technology suppliers are expected to benefit by understanding which TSN features are required to allow OEMs and higher-tier suppliers to implement conformant aerospace onboard networks.

2. Normative references

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

IEEE Std 802®, IEEE Standard for Local and metropolitan area networks: Overview and Architecture.[2,3]

IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control (MAC) Service Definition.

IEEE Std 802.1AS™, IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.

IEEE Std P802.1ASdm/D2.0 IEEE Draft Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications, Amendment: Hot Standby and Clock Drift Error Reduction.

IEEE Std 802.1CB™, IEEE Standard for Local and metropolitan area networks—Frame Replication and Elimination for Reliability.

IEEE Std 802.1Q™, IEEE Standard for Local and metropolitan area networks—Bridges and Bridged Networks.

IEEE Std 802.3™, IEEE Standard for Ethernet.

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

IEEE Std 1588a-2023, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems Amendment 3: Precision Time Protocol (PTP) Enhancements for Best Master Clock Algorithm (BMCA) Mechanisms

IETF RFC 7950, The YANG 1.1 Data Modeling Language, August 2016.

IETF RFC 8343, A YANG Data Model for Interface Management, March 2018.

[2] IEEE publications are available from The Institute of Electrical and Electronics Engineers (https://standards.ieee.org/).
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3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[4]

This standard makes use of the following terms defined in IEEE Std 802®.

— end station
— frame

This standard makes use of the following terms defined in IEEE Std 802.1Q.

— Centralized Network Configuration (CNC)
— Centralized User Configuration (CUC)
— Bridge
— packet
— policing
— Stream
— Tagged frame
— Talker

The following terms are specific to this standard:

end system: in his standard, a system attached to a network that is an initial source or a final destination of data transmitted across that network

NOTE—The term “end system” is often used in this document in places where the reader of IEEE 802 standards would expect the term, “end station,” in order to avoid confusion caused by standards relating to routers. For example, a router, as defined by IETF, is an IEEE 802 “end station,” but not an “end system.” Where this standard specifically refers to the use of IEEE 802 services, the term “end station” is used.

onboard: A system, systems or that is, or are, permanently installed on the aerospace platform. This does not include test or instrumentation systems or systems installed on the ground to support platform operations.

traffic: A sequence of frames forwarded in a network.

time-aware: An adjective to describe use of time that is synchronized with other stations using a protocol (e.g., IEEE Std 802.1AS).

[4] *IEEE Standards Dictionary Online* is available at https://dictionary.ieee.org.

4. Abbreviations and acronyms

The following abbreviations and acronyms are used in this standard: [5]

ACD	Airvraft Control Domain
ATS	Asynchronous Traffic Shaping
AV	Audio/Video
BNF	Backus-Naur Form
BTCA	Best timeTransmitter Clock Algorithm
CBS	Credit Based Shaper
C-DA	Customer Destination MAC address
C-TAG	C-VLAN tag
C-VID	Customer VLAN Identifier
C-VLAN	Customer Virtual Local Area Network
CFM	Connectivity Fault Management
CID	Company ID [6]
CNC	Centralized Network Configuration
CUC	Centralized User Configuration
DAL	Design/Development Assurance Level
DoS	Denial of Service
FTTM	Fault-Tolerant Timing Module
GM	Grandmaster
ICD	Interface Control Document
IMA	Integrated Modular Avionics
IP	Internet Protocol
LAN	Local Area Network (IEEE Std 802)
LLC	Logical Link Control
MAC	Medium Access Control
NETCONF	Network Configuration Protocol
PCS	Profile Conformance Statement
PICS	Protocol Implementation Conformance Statement
PIESD	Passenger Information and Entertainment Services Domain
PTP	Precision Time Protocol (IEEE Std. 1588)
QoS	Quality of Service
TAS	Time Aware Shaper
TSN	Time-Sensitive Networking
VMS	Vehicle Mission SystemTime-Sensitive Networking
YANG	Yet Another Next Generation [7]

[5] The abbreviations listed include those defined in standards referenced by this profile and used in this profile.
[6] See https://standards.ieee.org/develop/regauth/tut/eui.pdf.
[7] YANG is best viewed as a name, not an acronym.

5. Conformance

This clause specifies mandatory and optional capabilities provided by conformant implementations of systems, system components, and system functions for use in aerospace onboard Ethernet communications.

5.1 Requirements terminology

For consistency with existing IEEE and IEEE 802.1™ standards, requirements are expressed using the following terminology: [8]

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).

Profile Conformance Statements (PCS) reflect the occurrences of the words "shall," "may," and "should" within the standard.

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."

5.2 Profile Conformance Statement (PCS)

A claim of conformance to a profile specified in this standard attests to the implementation of a system, system component, or system functionality specified in referenced standards with the profile's selection of, and constraints upon, system parameters and options.

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 relevant PCS proforma provided in Annex A of this standard, together with the Protocol Implementation Conformance Statements (PICS) for the referenced standards, as identified in the PCS.

5.3 Conformance Classes

This profile includes conformance requirements and options for bridges and end stations that support a multitude of aerospace use cases. While some TSN features are required for certain use cases, the use of such features may be non-optimal in other use cases. Therefore, this standard defines two profiles applicable to end stations and Bridge components. The Asynchronous profile defines an aerospace profile that is targeted towards implementations that do not require time synchronization and TSN features that are dependent on time synchronization. The Synchronous profile defines the requirements for aerospace networks that support both synchronous and asynchronous TSN features. In this regard, a device conformant to synchronous profile also supports requirements defined in asynchronous profile. The Asynchronous profile, is therefore a subset of Synchronous profile.

[8] Originally derived from ISO/IEC style requirements, and consistent with the terminology specified in the ISO/IEC Directives Part 2:2021, Clause 7 (http://www.iec.ch/members_experts/refdocs).

In each profile, this standard recognizes two types of devices, herein defined as Type1 and Type2, to distinguish more capable devices with abundant resources from less capable devices that are often resource constrained. Both types of classes apply to the two profiles, resulting in total of 4 potential conformance classes for each conformant component: Asynchronous Type1, Asynchronous Type2, Synchronous Type1, and Synchronous Type2. Aerospace implementations may include a mixture of Type1 and Type2 conformant devices as needed to provide the required system capabilities.

5.3.1 Type1 Conformance Class

The Type1 conformance class imposes fewer requirements than the Type2 conformance class and is expected to be used for smaller and less performant systems and those that have tighter cost constraints. Requirements for Type1 devices are described for Bridges in subclauses 5.4.2, 5.4.4, 5.5.2 and 5.4.4; and for end stations in subclauses 5.6.2, 5.6.4 and 5.7.4.

5.3.2 Type2 Conformance Class

The Type2 conformance class imposes more requirements than the Type1 conformance class and is expected to be used for higher performant and larger systems. Requirements for Type2 devices are described for Bridges in subclauses 5.4.3, 5.4.5, 5.5.3 and 5.5.5; and for end stations in subclauses 5.6.3, 5.6.5, 5.7.3 and 5.7.5.

Note: Potential aerospace deployments may use both Type1 and Type2 conformant devices in the same vehicle based on the system requirements.

5.4 Bridge component requirements

5.4.1 Common Bridge component requirements

A bridge component implementation claiming conformance to any conformance class in this document shall:

a) Support VLAN Bridge component requirements according to IEEE Std 802.1Q-2022, 5.4 except for items g), h), and o)
b) Support C-VLAN component requirements according to IEEE Std 802.1Q-2022, 5.5 except for item d)
c) Allow the FDB to contain Static and Dynamic VLAN Registration Entries (8.8) for more than one VID, up to a maximum of 4094 VIDs, according to IEEE Std 802.1Q-2022, 8.8.
d) Support the strict priority algorithm for transmission selection on each port for each traffic class according to IEEE Std 802.1Q-2022, 8.6.8.1
e) Support stream identification components according to IEEE Std. 802.1CB-2017, 5.3
f) Support Per-Stream Filtering and Policing (PSFP) according to IEEE Std 802.1Q-2022, 8.6.5.2 items a), b), and d)
    1) support the maximum SDU size filtering according to IEEE Std 802.1Q-2022, 8.6.5.3.1
    2) support the flow metering according to IEEE Std 802.1Q-2022, 8.6.5.5
    3) support the monitoring of PSFP as specified in 7.6.2.4
g) Support minimum number of stream identification and filtering entries as defined in Table 7-1
h) Support the management entities for configuration of bridge functions as specified in 7.5

5.4.2 Asynchronous Type1 Bridge component requirements

A bridge component claiming conformance to asynchronous Type1 class of this document, shall

a) Support common bridge component requirements according to 5.4.1
b) Support at least four queues according to IEEE Std 802.1Q-2022, 8.6.6

5.4.3 Asynchronous Type2 Bridge component requirements

A bridge component claiming conformance to asynchronous Type2 class of this document, shall

a) Support asynchronous Type1 bridge component requirements according to 5.4.2
b) Support FRER according to IEEE Std. 802.1CB-2017, 5.15
c) Support monitoring for FRER as specified in 7.6.2.5
d) Support the operation of the credit-based shaper algorithm according to IEEE Std 802.1Q-2022, 8.6.8.2 on all ports as the transmission selection algorithm for at least 2 traffic classes

5.4.4 Synchronous Type1 Bridge component requirements

A bridge component claiming conformance to synchronous Type1 class of this document, shall

a) Support common bridge component requirements according to 5.4.1
b) Support at least eight queues according to IEEE Std 802.1Q-2022, 8.6.6
c) Support at least 2 PTP Instances according to IEEE Std 802.1AS-2020, clause 5.4.1 items a) through e) and g) through j) on all physical ports
d) Support external port configuration capability on all ports according to IEEE Std 802.1AS-2020 5.4.2 item g)
e) Support PSFP stream gating according to IEEE Std 802.1Q-2022, 8.6.5.2 item c)
f) Support the enhancements for scheduled traffic as specified in IEEE Std 802.1Q-2022 8.6.8.4 on all ports
g) Support the state machines for scheduled traffic as specified in IEEE Std. 802.1Q-2022, 8.6.9
h) Support the monitoring requirements of scheduled traffic as specified in 7.6.2.2
i) Support the stream gating for PSFP as specified in IEEE Std 802.1Q-2022, 8.6.5.4 and 8.6.10

5.4.5 Synchronous Type2 Bridge component requirements

A bridge component claiming conformance to synchronous Type2 class of this document, shall

a) Support synchronous Type1 bridge component requirements according to 5.4.4
b) Support at least 3 PTP Instances according to IEEE Std 802.1AS-2020, clause 5.4.1 items a) through e) and g) through j) on all physical ports
c) Support FRER according to IEEE Std. 802.1CB-2017, 5.15
d) Support monitoring for FRER as specified in 7.6.2.5
e) Support the operation of the credit-based shaper algorithm according to IEEE Std 802.1Q-2022, 8.6.8.2 on all ports as the transmission selection algorithm for at least 2 traffic classes

5.5 Bridge component options

5.5.1 Common Bridge component options

A bridge component implementation claiming conformance to any conformance class in this document may:

a) Allow translation of VIDs through support of the VID Translation Table or through support of both the VID Translation Table and Egress VID translation table on one or more Bridge Ports according to IEEE Std 802.1Q-2022, 6.9

5.5.2 Asynchronous Type1 Bridge component options

A bridge component implementation claiming conformance to asynchronous Type1 conformance class in this document may:

a) Support the operation of the credit-based shaper algorithm according to IEEE Std 802.1Q-2022, 8.6.8.2 on all ports as the transmission selection algorithm for all traffic classes

b) Support at least eight queues according to IEEE Std 802.1Q-2022, 8.6.6

5.5.3 Asynchronous Type2 Bridge component options

A bridge component implementation claiming conformance to asynchronous Type2 conformance class in this document may:

a) Support at least eight queues according to IEEE Std 802.1Q-2022, 8.6.6

b) Support Active Destination MAC and VLAN Stream identification functions for encoding and decoding packets according to IEEE Std 802.1CB-2017, 6.6

5.5.4 Synchronous Type1 Bridge component options

A bridge component implementation claiming conformance to synchronous Type1 conformance class in this document may:

a) Support the operation of the credit-based shaper algorithm according to IEEE Std 802.1Q-2022, 8.6.8.2 on all ports as the transmission selection algorithm for all traffic classes

b) Support at least 3 PTP Instances according to IEEE Std 802.1AS-2020, clause 5.4.1 items a) through e) and g) through j) on all physical ports

5.5.5 Synchronous Type2 Bridge component options

A bridge component implementation claiming conformance to synchronous Type2 conformance class in this document may:

a) Support Active Destination MAC and VLAN Stream identification functions for encoding and decoding packets according to IEEE Std 802.1CB-2017, 6.6.

5.6 End station component requirements

5.6.1 Common end station component requirements

An end station component claiming conformance to any conformance class in this document shall

a) Support the strict priority transmission selection algorithm according to IEEE Std 802.1Q-2022, 8.6.8.1 on all ports for at least two traffic classes
b) Support the operation of the credit-based shaper algorithm according to IEEE Std 802.1Q-2022, 8.6.8.2 on all ports as the transmission selection algorithm for at least two traffic classes
c) Support management entities for configuration of the end station as specified in 7.5

5.6.2 Asynchronous Type1 end station requirements

An asynchronous Type1 end station that conforms to the provisions of this standard shall:

a) Support the common end station component requirements of 5.6.1

5.6.3 Asynchronous Type2 end station component requirements

An asynchronous Type2 end station that conforms to the provisions of this standard shall:

a) Support the asynchronous Type1 end station requirements of 5.6.2
b) Support the FRER Talker end system required behaviors as specified in IEEE Std 802.1CB-2017, Clause 5.6.
c) Support the FRER Listener end system required behaviors as specified in IEEE Std 802.1CB-2017, Clause 5.9
d) Support the monitoring requirements of FRER as specified in 7.6.2.5

5.6.4 Synchronous Type1 end station component requirements

A synchronous Type1 end station that conforms to the provisions of this standard shall:

a) Support the common end station component requirements of 5.6.1
b) Support at least 2 PTP Instances according to IEEE Std 802.1AS-2020, 5.4.1 items a) through e) and g) through j) on all physical ports
c) Support external port configuration capability on all ports according to IEEE Std 802.1AS-2020 5.4.2 item g)
d) Support end station requirements for enhancements for scheduled traffic according to IEEE Std 802.1Q-2022, 5.25
e) Support the monitoring requirements of scheduled traffic as specified in 7.6.2.2

5.6.5 Synchronous Type2 end station component requirements

A synchronous Type2 end station that conforms to the provisions of this standard shall:

a) Support the synchronous Type1 end station component requirements of 5.6.4
b) Support at least 3 PTP Instances according to IEEE Std 802.1AS-2020, 5.4.1 items a) through e) and g) through j) on all physical ports
c) Support the FRER Talker end system required behaviors as specified in IEEE Std 802.1CB-2017, Clause 5.6
d) Support the FRER Listener end system required behaviors as specified in IEEE Std 802.1CB-2017, Clause 5.9
e) Support the monitoring requirements of FRER as specified in 7.6.2.5

5.7 End station component options

5.7.1 Common end station component options

An end station component claiming conformance to any conformance class in this document may:

a) Support the use of customer VLAN identifiers
b) Support the use of per-stream VID and PCP
c) Support at least eight queues according to IEEE Std 802.1Q-2022, 8.6.6

5.7.2 Asynchronous Type1 end station component options

No options are identified for asynchronous Type 1 end stations.

5.7.3 Asynchronous Type2 end station component options

An asynchronous Type2 end station that conforms to the provisions of this standard may:

a) Support operation of the per-stream credit-based shaper algorithm for more than one stream according to talker behavior as specified in IEEE Std 802.1Q-2022, 34.6.1.1
b) Support FRER stream splitting function as specified in IEEE Std. 802.1CB-2017, clause 7.7 on more than one port and for some number of Compound Streams greater than 1
c) Support FRER talker end system required as specified in IEEE Std. 802.1CB-2017, clause 5.6 on more than one port
d) Support FRER talker end system required as specified in IEEE Std. 802.1CB-2017, clause 5.6 for some number of Compound Streams greater than 1
e) Support FRER listener end system required behaviors as specified in IEEE Std. 802.1CB-2017, clause 5.9 on more than one port
f) Support FRER listener end system required behaviors as specified in IEEE Std. 802.1CB-2017, clause 5.9 for some number of Compound Streams greater than 1

5.7.4 Synchronous Type1 end station component options

A synchronous Type1 end station that conforms to the provisions of this standard may:

a) Support at least 3 PTP Instances according to IEEE Std 802.1AS-2020, 5.4.1 items a) through e) and g) through j) on all physical ports

5.7.5 Synchronous Type2 end station component options

A synchronous Type2 end station that conforms to the provisions of this standard may:

a) Support FRER stream splitting function as specified in IEEE Std. 802.1CB-2017, clause 7.7 on more than one port and for some number of Compound Streams greater than 1
b) Support FRER talker end system required as specified in IEEE Std. 802.1CB-2017, clause 5.6 on more than one port
c) Support FRER talker end system required as specified in IEEE Std. 802.1CB-2017, clause 5.6 for some number of Compound Streams greater than 1
d) Support FRER listener end system required behaviors as specified in IEEE Std. 802.1CB-2017, clause 5.9 on more than one port
e) Support FRER listener end system required behaviors as specified in IEEE Std. 802.1CB-2017, clause 5.9 for some number of Compound Streams greater than 1

6. Aerospace Onboard Networks (informative)

This informative clause provides the context necessary to understand the network functions (Clause 7) required in aerospace onboard networks and inform the profiles (Clause 8) specified by this standard. It provides a general introduction to onboard aerospace networks (6.1) and describes the following topics:

a) Network design constraints (6.2)
b) Network topologies (6.3)
c) Application and traffic characteristics (6.4)

Note: This clause does not limit the aerospace profile to the use cases described within the clause. The profile as defined by Clause 5 of this standard is expected to be used by industry for all relevant applications.

6.1 Introduction to Aerospace Networks

Aerospace networks architectures can be broadly categorized by use cases from either a commercial or military perspective and analyzed from either a current or future perspective.

6.1.1 Current Network Architectures

Current network architectures in aerospace are often domain based, wherein a domain defines a set of functional communication blocks (e.g. aircraft control domain, vehicle management domain, etc.). Domains are isolated by physically separate networks. Furthermore, within a given domain there are sub-domains that are also segregated into physically separate networks. For example, in the aircraft control domain, the fly-by-wire (or flight control) network is a separate network from the avionics network.

The current aerospace use cases also limit the use of Ethernet to lower criticality communications, which are not necessarily flight critical. For example, fly-by-wire networks on existing aircraft are based on non-Ethernet data buses.

6.1.1.1 Commercial Aircraft

Networks are used in commercial aircraft to support varying levels of capabilities from supporting passenger entertainment to the actual control of the aircraft. Modern commercial aircraft can be subdivided into three networking domains: Aircraft Control Domain (ACD), Airline Information Services Domain (AISD), and the Passenger Information and Entertainment Services Domain (PIESD) as shown in Figure 6-1.

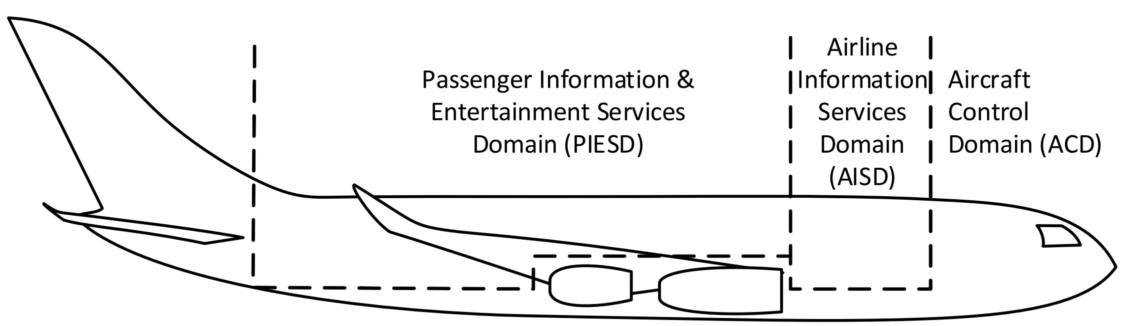

Figure 6-1—Commercial Aircraft Network Domains

The Aircraft Control Domain (ACD) networks host equipment that contribute to the safe flight of the aircraft. Functions typically hosted on the ACD network include electronic flight display systems, engine monitoring and alerting systems, flight management systems, flight controls, and other control systems that are housed outside of the passenger cabin. Due to the high criticality of the functions hosted, the ACD network has high safety requirements and deterministic [9] behavior is required.

In the ACD, networks were initially brought on the aircraft in order to reduce size, weight, and power (SWaP). Before that, functions allocated to dedicated equipment were connected by low- bandwidth point to point data buses such as ARINC 429 or RS-485. Modern aircraft often now employ Integrated Modular Avionics (IMA) that provides shared resources and reduces the amount of equipment and wiring on the aircraft. In an IMA system, a general purpose processor is used to host software applications from multiple systems and a high-speed network provides an interconnect between the IMA processing, other function-specific equipment and to data concentrators that provide connections to legacy interfaces. SWaP savings occur due to the reduced equipment count and a reduction in wiring due to consolidation. Figure 6-2 depicts a notional IMA system.with processing elements, network switches and data concentrators,

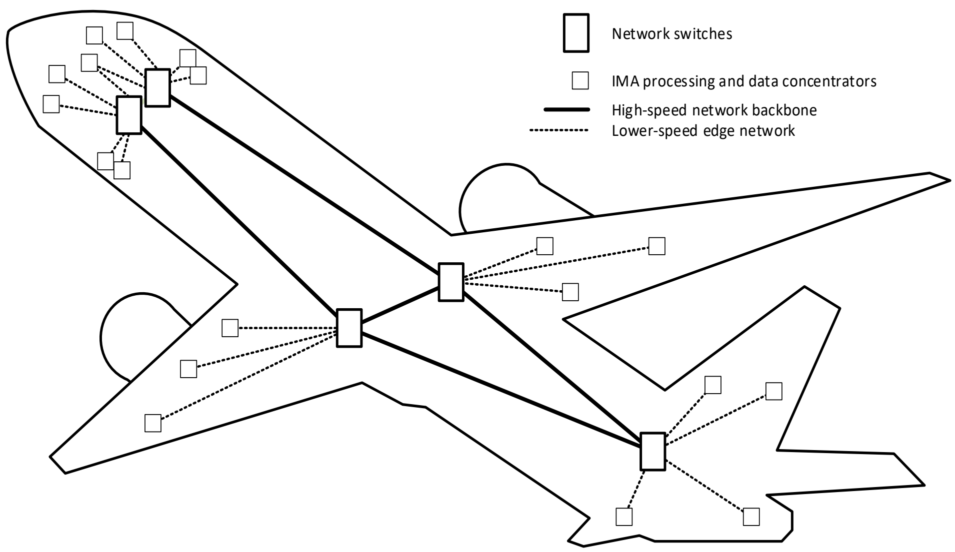

Figure 6-2—Commercial Integrated Modular Avionics Depiction

The Airline Information Service Domain (AISD) supports non-essential airline operational activities. It typically provides a general purpose processing platform as well as connectivity off the aircraft and between the other domains on the network. The AISD has high security requirements, but limited safety and determinism requirements due to the non-essential functions supported.

The Passenger Information and Entertainment Services Domain (PIESD) provides passenger network and entertainment services. On large commercial aircraft, this includes supporting the needs of hundreds of passengers. This drives high performance requirements. Interestingly, the PIESD has high availability requirements based on customer expectations.

6.1.1.2 Military Aircraft

Military aircraft also use onboard networks to support functionality from the flight critical to mission oriented. A military aircraft can be subdivided into two domains: Air Vehicle System (AVS) and Vehicle Mission System (VMS). The AVS of the military aircraft is similar to the ACD of commercial aircraft. It encompasses the systems necessary for safe flight of the aircraft.

[9] The meaning of determinism can vary with the use case and might range from microsecond timing control to bounded timing behavior in the 1-100 millisecond range.

The Mission System of the military aircraft is responsible for supporting the varied missions of the aircraft. Depending on the type of aircraft, this could be delivering a weapon, search-and-rescue operations, and transport of equipment or personnel. The requirements for the VMS network vary based on the mission equipment installed. The VMS equipment may include one or more high performance mission computers and typically has higher bandwidth needs than the AVS.

6.1.2 Future Network Architectures

As described in clause 6.1, the current aerospace network architectures tend to be domain based with multiple sub-domains in each domain. This poses a challenge to future platforms that require significant inter-domain communications coupled with more stringent size, weight and power, and cost (SWaP-C) requirements. Zonal architectures provide one solution to address these challenges and reduce the cabling needs in the aircraft while simultaneously converging the different-data buses.

Traditional aerospace system architectures have evolved from a domain, or function, based approach where each system was designed in isolation and overlaid onto the vehicle hardware in such a way that independent interconnects were often provided in the same physical areas. However, more recent approaches in civil, military, and also satellite platforms, have adopted a zonal approach where data is consolidated locally and communicated over shared buses between zones, often involving shared I/O and processing components. This zonal approach relies on logical separation of functions over a shared infrastructure rather than on physical separation as has traditionally been the case and reduces the duplication of interconnect infrastructure to provide the required level of fault-tolerance. By supporting the partitioning of traffic flows, TSN supports the convergence of application functions onto a single physical network to reduce weight and cost by eliminating separate physical networks. In an example of this approach, it might be possible to envisage a flight control, or weapon release system, sharing network resources with a video distribution system.

Time-sensitive networking supports future networks and enables features that are required for the full range of use cases and traffic types to implement functions with a single network technology. Thus, adoption of TSN would allow for a significant increase in the scale of onboard Ethernet networks (i.e., the number of end stations, Bridges, and streams).

6.2 Network Design Constraints

Although there is considerable variability in the requirements and use cases of commercial and military aircraft, the aerospace profile of TSN attempts to balance the requirements of these use cases.

As in any system, the primary purpose of the network is to support the system and enable it to fulfill it’s design objectives. The functional aspects of this are ultimately measured through technical performance provided by the networking technology, typically interpreted as the ability to transport data from A to B in a time *T*, however this performance must be measured against market factors as well as regulatory constraints imposed on the aerospace industry. These factors are discussed here briefly to provide an overview of the design constraints that frame the aerospace TSN profile.

6.2.1 Performance & Technology

Performance is addressed here through quantifiable physical characteristics whereas technology is addressed through qualitative measures related to the use of the technology in an avionics system.

Each unique use case has differing requirements related to the bandwidth needs of connected nodes, the latency required for transmission of data through the network, and for the level of determinism needed to support individual applications. Bandwidth needs for VMS are often orders of magnitude greater than for

ACD and the aggregate bandwidth needs for PIESD are increasing, as driven by passenger expectations and demand.

Hand in hand with the increased bandwidth needs for mission or passenger networks, the need for tight control of latency and jitter to support streaming services, whether this be for sensor data or for audio and video streams, drives the need for quality-of-service provision. Commercial transport aircraft, and some military platforms, have been using the quality-of-service provisions of ARINC 664 Part 7 for many years to provide bounded latency determinism to support of aircraft system functions and this is expected to be expanded by the addition of closed loop control functions that require strict delivery deadlines associated with mechanical and electronic control systems.

Determinism can also be considered to include the need for guaranteed delivery, and whilst true guaranteed delivery has typically been deferred to individual applications and aircraft functions, increased availability of data through provision of redundant data paths and redundant data sources has been, and will continue to be, the predominant means of ensuring data delivery in the aerospace network.

Demonstration of determinism, or at least proof thereof, has been central to the regulatory framework for many years and widespread adoption of what is essentially an asynchronous communication medium places stringent requirements on aerospace system designers to show aviation safety authorities, either by demonstration or by mathematical analysis, that network latencies can meet the safety requirements of the systems hosted on the various aircraft networks.

Security is rapidly becoming a central theme for aerospace systems and security features common in modern infrastructure networks are expected to be adopted in aerospace networks. Whether this is through authenticated access mechanisms and secure networks, or secure partitioning of network domains, physical security is no longer going to be the default operating paradigm.

Central to the reason for adoption of Ethernet as the preferred networking technology for aerospace networks, as has been seen over the last 20-30 years, are the levels of standardization and interoperability seen amongst a wide range of suppliers, as well as the ability to accommodate physical as well as functional growth that this standardization has brought. The availability of integration and test equipment and tools brought over from telecommunications, industrial and automotive markets also plays a large part in the attractiveness of Ethernet based networks to the aerospace industry.

6.2.2 Market Factors

Market factors impact all the anticipated use cases in aviation and TSN can be seen to offer clear technical and economic advantages that are made more compelling by the development of a profile specifically targeting Aerospace applications.

TSN is not a separate standard but comprises a set of amendments to the IEEE standard for Bridges and Bridged Networks to support time-aware functions. With the wide set of features that comprise TSN it is imperative that both operators and suppliers agree on a subset of the standards that are needed to avoid a situation where different components claim to support TSN but do not support the same set of TSN standards and are not inter-operable at the equipment level. The development of an industry profile to constrain the use of TSN standards is therefore a critical component that leads to a uniform supplier base to minimize the developmental and operating costs for aerospace networks.

Flexibility to support multiple traffic profiles with a single networking technology that is widely available and conforms to open standards, notwithstanding any dissimilarity needs, reduces the life-cycle costs of the aircraft by limiting variation in technology and equipment for maintenance and support tasks. Supported systems and functions may or may not be on the same physical network.

The larger industrial ecosystem that results from the use of open standards, and the natural evolution that arises from sharing these with wider industry, should lead to more reliable supply chain options and longevity in that supply chain to support the long service life that is expected in the aerospace industry.

6.2.3 Regulatory Considerations

The use cases described in section 6.3 cover the full range of aviation functional hazard classifications ranging from no functional effect through to catastrophic effect. An aerospace TSN network therefore needs to be developed following processes agreed with safety authorities responsible for oversight of the selected application. By harmonizing the use of TSN within the aerospace community it becomes possible to gain consensus between users of the technology and the applicable safety authorities for how the various TSN capabilities can meet the required safety standards. It is not in the scope of this standard to provide support for demonstrating the compliance of a TSN implementation with the appropriate regulations governing the particular application.

Central to the arguments for safety of the systems supported by the TSN network are established mechanisms for analyzing the probability of faults that lead to impaired system functionality, whether this relates to the equipment providing the network services or to the behavior of the functions implemented on that equipment. With regard to the functions provided by TSN, defining the constraints within which these functions operate greatly simplifies the effort required to demonstrate a level of determinism appropriate to the intended scope of operation and to thereby analyze the effects of failures associated with each of the performed functions.

Whether this relates to such failures as loss of synchronization and the methods needed to reduce the chance of this to an acceptable level, or the failure of filtering mechanisms in equipment that forms a part of the network, techniques can be agreed for the analysis of these failures and then reused across similar applications.

Without involvement of industry or government safety authorities, or details of specific network implementations, it is not possible or appropriate to propose or describe methods for achieving regulatory approval for the application of TSN networks in aerospace applications. This purpose of this TSN profile is therefore limited to supporting commonality between applications and reducing to number of analyses that need to be considered.

6.3 Network topologies

Network topologies for a range of aerospace platform use cases have been analyzed and are summarized here to inform the reader of potential use cases that have been considered in the development of this profile. The inclusion of a use case does not necessarily mean that the TSN profile shall support the use case. Similarly, the exclusion of a use case does not imply that it is not supported by the TSN

The aerospace use cases examined to develop a summary of use cases are listed below. Abbreviations are used as described in 6.1.1above.

— Small Business Aircraft - ACD/AISD
— Large Passenger Aircraft - ACD/AISD
— Large Passenger Aircraft - PIESD
— Small and Combat Military Network - AVS
— Small and Combat Military Network - VMS
— Large Military Network - VMS
— Unmanned Military Network - AVS & VMS
— Rotary Wing Aircraft - AVS
— Rotary Wing - VMS

— Satellite Network
— Fibre Channel over TSN Backbone (AS6509)

The individual use cases can be analyzed from the perspective of various qualitative and quantitative characteristics to provide fair comparisons. The characteristics defined in Table 6-1 denote characteristics of the physical medium.

Table 6-1—Use Case Characteristics

Characteristic	Description
Number of Nodes	Denotes the total number of networking nodes in an instantiation of the use case. Includes both end stations and Bridges. May be specified as a range or a maximum value.
Physical Topology	Denotes the type of physical topology in use, where in “physical topology” represent the hardware level connectivity between devices. Examples include star, ring, mesh, and point-to-point/multipoint. One or more topologies may be specified.
Number of Switch Hops	Denotes the number of hops between source and destination. May be specified as a range or a maximum value.
Max Number of Streams per Switch	Denotes the number of unique data streams traversing a Bridge in the network. Each unique stream requires the Bridge to perform stream identification, stream policing, and optionally stream shaping. These functions serve the overall aerospace requirement that the Bridge is able to maintain isolation between unique data streams and provide guaranteed quality of service for each data stream. May be specified as a range or a maximum value.
Network Redundancy	Describes the network redundancy architecture in the current instantiations of the use case. One of more redundancy architectures may be specified.
Redundancy Mode	Denotes the mode of redundancy. Options include standby, active, hot-active, active-active with voting. One or more modes may be specified.
Data Rates	Denotes the data rate(s) of the physical media. May be specified as one or more rates
Media type	Denotes the type of media, which may include the physical medium as well as MAC protocol. Examples include 100BASE-TX, Shielded Twisted Pair. May be specified as one or more media types.
Worst Case Link Utilization	Denotes the link utilization of the most congested link in the network. Due to aerospace certification requirements, the worst case link utilization as designed/configured may be different from the worst case utilization as realized on the wire. This field can be used to specify both the “as configured” and “as realized on wire” variants of the link utilization. May be specified as a range or maximum value.
Dissimilarity, Integrity, & Security	When applicable, denotes the use of dissimilarity, integrity, & security features. Additionally, the method by which such a feature is achieved in the current instantiation of the use case may be specified.
Maintenance and Monitoring	When applicable, denotes the use of maintenance and monitoring features. Additionally, the method by which such a feature is achieved in the current instantiation of the use case may be specified.
Certification Requirements	Specify if any certification requirements apply to this use case. Specify if it is Mandatory, Desired, Do Not Care.
Supported Traffic types	Listing of Traffic Types from section 6.4 that exist in this use case.

The use case characteristics presented during development of this standard [B3] are summarized in Table 6-2 and discussed in the following sub-sections. The list is not intended to be exhaustive, but provides typical use cases considered sufficient to drive development of the standard.

Table 6-2—Summary of Aerospace Use Cases

Characteristic	Current Use		Known/ Desired Future Use	Use case driving the most restrictive bound
	Lower Bound	Upper Bound		
Number of Nodes	5	100	500	Large Passenger Aircraft (ACD)
Physical Topology	Bus (command/response protocol), Point-to-point/ multipoint, Ring (daisy chained), switched star or combination		Hybrid - Ring and Star	N/A
Number of Switch Hops	0	5	15-30	Large Passenger Aircraft (PIESD)
Max Number of Streams per Switch	50	2000	4096	Large Passenger Aircraft (ACD)
Network Redundancy	Two independent networks (A,B). End systems are dual homed to redundant LANs (ARINC664 part 7); Fault-tolerant Ring; None on point-to-point links. Subsystem or full system level redundancy (dual, triple, or quad)		same as current use cases	All fault-tolerant use cases
Redundancy Mode	Bus Failover (Hot Standby), Frame Failover (Hot Active); Hot Active with voting		same as current use	DAL[*] A/B systems
Data Rates	10 Kbps	1 Gbps	100 Gbps	MIL-STD-1553 and Satellites on the low bound. Military VMS on the high end.
Media type	Copper: 1394,1553, RS-485/422, ARINC 429/629, Ethernet. Multimode Fiber: Fibre Channel, 100BASE-SX and 1000BASE-SX		Optical fiber for higher data rates	All aircraft
Worst Case Link Utilization	95% (worst case-configured) 80% (realized on the wire); higher for deterministic buses		reduced to support application growth	Large passenger aircraft for configured, Military Flight Networks for realized
Dissimilarity, Integrity, & Security	No dissimilarity, integrity, or security features	Dissimilarity in design/implementation, high integrity additions, monitoring, security for isolation between assurance levels and cross-domain traffic	no change	Flight critical systems (e.g. ACD in large passenger aircraft, or AVS in military vehicles)
Maintenance and Monitoring	No maintenance or monitoring functions	Monitoring/Maintenance with SNMP or other means	Mandatory MIBS for TSN Network	Systems requiring high utilization.
Certification Requirements	None, self certified	HW/SW design and development assurance; IMA and Safety	no change	Passenger Aircraft (ACD)
Supported Traffic types	All traffic types		no change	All aircraft

[*]Design/Development Assurance Level according to SAE ARP4754

6.3.1 Number of Nodes

Control domains (ACD or AVS) typically have between 10 and 100 nodes depending upon the size and extent of the network and this is expected to remain constant going forward in time. The lower bound represents smaller military vehicle and satellite applications but these are expected to increase as more systems are added to the main networks.

Going forward the main driver for expanding the network comes from large passenger aircraft where airline and passenger information and entertainment networks (AISD & PIESD) are expected to grow as airlines compete through provision of improved passenger experiences.

6.3.2 Physical Topology

Almost all conceivable network topologies can be found across the aerospace use cases examined, and this is expected to remain the case going forward.

The most common topology encountered is that of a switched star, with larger networks cascading switches so that traffic traverses a number of switch hops to reach it’s final destination. Ring networks are also important, particularly where switches are impractical or where bandwidth demands are high, providing one of the main drivers for Bridged end stations. Ring networks are most commonly found in military applications. Point to point links are also found where bandwidth requirements or weight restrictions make the use of switches impractical.

Redundancy and availability requirements complicate the network topology discussion. Civil passenger aircraft often employ redundant networks with dual-ported end stations as typified by ARINC 664 Part 7 networks. Elsewhere, redundant paths can be seen to provide redundancy in a single unified network. Both of these examples further driving the need for Bridged end stations and frame redundancy mechanisms.

6.3.3 Number of Switch Hops

The number of switch hops is largely an outcome of the size of the network and a trade off between switch size/capacity and wire-weight. Latency and determinism requirements have tended to put an upper bound on the number of switch hops. However, the reduced latency available with time-sensitive networking is likely to see the number of hops increase, particularly in larger cabin applications.

6.3.4 Max Number of Streams per Switch

The number of streams per switch is largely driven by the size and complexity of the network, and is usually controlled by the system integrator as part of the network configuration. Whilst ARINC 664 Part 7 specifies a minimum of 4096 streams, or Virtual Links, per switch this is not seen in current networks. However, as networks become larger, particularly for large passenger aircraft and with the addition of small devices to current networks, this number of streams is expected to be realized and may expand to as many as 10,000 streams.

The number of streams per switch must also be balanced against the practicalities of the technology and whilst the majority of aerospace use cases are expected to be met through the use of commercial technology the limits of that technology must also be considered. The future upper bound of 4096 streams is therefore considered a reasonable compromise.

6.3.5 Network Redundancy

Where network redundancy is required, current use cases most commonly achieve this by implementing two independent (A,B) networks and dual-homed end nodes (e.g. ARINC 664 Part 7). TSN Ethernet offers additional methods for achieving redundancy, including use of mesh or ring networks, and use of bridged end stations as well as dual-homed end nodes.

Point-to-point links do not by themselves provide redundancy unless this is managed at the system level where dual, triplex or sometimes quad redundancy may be encountered.

6.3.6 Redundancy Mode

A variety of redundancy mechanisms can be found, with bus fail-over (hot standby), frame fail-over (hot active) and hot active with voting being the most common.

6.3.7 Data Rates

Data rates, particularly at the lower bound, are largely tied to the historical/legacy systems that are being migrated to an Ethernet based network. At the upper bound, data rates have been limited by available technologies with high bandwidth applications being migrated from older RF links and bespoke transmission schemes. Future uses are expected to follow advances in commercial technology with 100 Gbps Ethernet seen as the most likely next step in performance.

6.3.8 Media type

Aerospace applications have traditionally relied on copper interconnects as there is a long established acceptance of the technology and an understanding of how to install the technology in the specific environment. This has led to the situation where lower speed Ethernet links also use copper media for lower speeds (below 100 Mbps) and shorter distances.

The advent of higher aggregate data rates and high bandwidth data streams are however driving a need to adopt optical fiber media for anything above 100 Mbps.

6.3.9 Worst Case Link Utilization

Driven by the desire to stay with copper media interfaces and the ability to statically configure networks for determinism, link utilization has been pushed to the limit in the worst case analysis. Because this is very much a worst-case analysis, to provide evidence of bounded latency determinism, the reality is that this level of utilization is extremely rare and the reality is usually well below 50%.

However, In rare cases this level of utilization can also be encountered in practice when tight control of the traffic is managed by a single function or application. In these cases, provided that the system integrator can demonstrate control of the traffic loading then 80% or even higher utilization might indeed be encountered.

6.3.10 Dissimilarity, Integrity, Maintenance, Monitoring, Security [DIMMS]

Dissimilarity and integrity tend to be associated with safety critical systems and are generally mandated by the relevant aviation safety authorities, particularly with regard dissimilarity. Both of these come at considerable cost in an aerospace environment but are essential for certain systems.

Maintenance operations, whilst important to the end user, are often afforded a lower importance by the OEM because they do not directly contribute to the aircraft function and are therefore harder to place a value on. Monitoring however is crucial as this relates to the assessment of continued safe operation of the system and fall within the purview of the aviation safety authorities.

Security in the realm of aerospace networks should not be confused with cybersecurity, although there is certain commonality involved. Whereas cybersecurity addresses the activities performed by an organization to safeguard its digital assets, security relates most simply to the protection of information from unauthorized interaction. In the aerospace network security therefore relates to the physical and logical separation of network domains. Most commonly mandated for military networks security is becoming more relevant to civil aircraft networks, particularly where data is shared between network domains such as the AISD and PIESD. Robust logical partitioning, through VLANs, and cross-domain security therefore become increasingly important for aerospace networks.

6.3.11 Certification Requirements

Certification requirements are generally set by the safety authority responsible in the domain in which the platform is intended to operate. For civil applications this is generally a national or regional organization, whereas for military applications the acquisition organization may be responsible, following guidelines such as, but not limited to, DO-254 [B6], DO-178 [B5], ARP4754 [B7] and ARP4761 [B8], as set by one or more of the civilian authorities. Satellite systems may be regulated by the European Cooperation for Space Standardization (ECSS) or similar organizations.

The responsible safety authority will set standards for developmental design assurance to ensure that equipment, systems and aircraft are safe to operate within a defined scope. In relation to time-sensitive networking this will include oversight of activities intended to show that the network will provide the intended behavior and performance consistent with it's intended application and may include test or mathematical analysis consistent with acceptable means of compliance as outlined by the authority.

Specification of the certification requirements for a time-sensitive network is outside of the scope of this profile document.

6.3.12 Supported Traffic types

Traffic types are described in detail in 6.4 but a generic listing of current traffic types is provided here for information.

- File Transfers - Mission Loading, Video Transfer, Image Transfer, Nav/Map data
- Asynchronous Parametric Data – sensors, displays,
- Synchronous Parametric Data – closed loop control and Inertial
- Command and Control – Weapons release authorization, commands
- Audio Streaming – Cockpit audio, cabin PA,
- Video Streaming – Uncompressed real-time video (ARINC818), compressed video streams
- Maintenance and Health Monitoring – fault reporting, testing
- Fiber Channel over TSN (FCoT) – HS1760 (weapons systems), and other FC based applications
- Extremely High BW Source - raw Radar data
- Raw IQ data and Raw Plot data
- Network control and infrastructure traffic

The different aerospace platforms will use traffic of these types in different mixes to achieve the desired behavior and performance. There is no correct mix of traffic types.

6.4 Application and traffic characteristics

Aerospace applications have been analyzed here in terms of the traffic that they use to communicate. This has been performed in a two-step process where first the characteristics used to define the traffic were defined and second where example applications were analyzed using the defined characteristics to provide a summary of the traffic types used in aerospace applications. The applications analyzed and their characteristics are not exhaustive but illustrate the complete range of traffic types that are encountered in typical aerospace applications on an aerospace network.

6.4.1 Traffic Type Characteristics

Traffic type characteristics are listed in Table 6-3 that enable a comparison of the most common traffic types encountered in the aircraft applications that are described in Table 6-1 and Table 6-2.

Table 6-3—Aerospace Traffic Type Characteristics

Characteristic	Description
Periodicity	Traffic types comprise data streams that can either be **Periodic**: transmitted in a cyclic/periodic (e.g. signal transmission) or **Aperiodic**: transmitted in a acyclic/sporadic (e.g. event-driven) manner
Typical Period	Period denotes the planned data transmission interval (often also called “cycle”) at the application layer. #: Specify period for cyclic traffic **N/A:** for aperiodic/acyclic traffic
Application Synchronized to Network	Is the application producing traffic type synchronized to the network time at the application layer? **YES** or **NO**
Data Delivery Guarantee Mode	Packet(s) are delivered to all receivers: **Deadline**: before a specified time, relative to cycle time. (applies to periodic data) **Latency**: within a predictable timespan from the start of the transmission **Bandwidth**: if bandwidth utilization is within in the resources reserved by the sender **None**: no special delivery requirements
Delivery Guarantee Value	**#**: Typical quantification of the data delivery guarantee for 80% of the use cases. If “deadline” mode is used, specifies if the data will be delivered in the same period or not.
Application Tolerant to Jitter	Application’s tolerance of a certain amount of latency variation of the packet’s transmission (a.k.a Jitter) **yes**: application can tolerate jitter as specified (always yes for “Bandwidth” and “none” delivery modes) **no**: highly sensitive application requires negligible jitter
Tolerable Jitter Value	**#**: Value of acceptable jitter for periodic applications **NEG**: Jitter must be negligible **N/A**: if data delivery guarantee mode is “bandwidth” or **“**none**”**
Application Tolerant to Packet Loss	An application’s tolerance to a certain amount of consecutive packet loss **Yes**: app can tolerate loss due to recovery mechanism in upper layer protocols or basic redundancy **No**: app cannot tolerate a single packet loss
Tolerable Packet Loss Value	**#**: Num of consecutive packet loss tolerable to app. **0**: if application is not tolerant to packet loss
Application Payload Size Variability	**fixed**: application payload size remain fixed **variable**: app payload varies from one packet to packet
Payload Value (Bytes)	**#**: size/range of application data (payload) to be transmitted in the Ethernet frames.
Data Criticality	Criticality of this data for operation of the critical parts of the system: **high**: highly critical for the operation. (DAL A, B), **medium**: relevant but not continuously needed for the operation (Dal C, D), **low**: not relevant for operation (DAL E).

6.4.2 Traffic Type Analysis Summary

The traffic use case analysis in tables 6-1 and 6-2 separated traffic types broadly into Military Aircraft and Commercial Aircraft groupings [B4]. The bounds of these traffic types are summarized here in Table 6-4.

Table 6-4—Summary of Aerospace Traffic Types

Traffic Characteristic	Current Use (range)		Known/ Desired Future Use Bound	Use Case Driving the Most Restrictive (right) Bound
	Left Bound (loosest)	Right Bound (tightest)		
Synchronism	Asynchronous	Synchronous	no change	Ultra-low latency and/or jitter (right bound)
Application synchronized to network?	No	Yes	no change	Ultra-low latency and/or jitter
Periodicity or Cycle Time	Aperiodic	<1 ms	100 µs	Flight critical controls, sensors, and weapon systems
Latency Mode Guarantee Value	100 ms	1 ms	100 µs	high criticality asynchronous events
Tolerance to interference (delay variation/ jitter)	up to latency limit	< 1 µs	no change	fly-by-wire, synchronous sensors
Tolerance to Loss*	3 consecutive frames	zero	no change	Parametric data (left bound), Flight control or weapon release (right bound)
Payload size	8 bytes	2112 bytes	no change	Sensor data (left bound) Fibre Channel over TSN (right bound)
Data Criticality	no safety effect	DAL A	no change	Safety critical and flight control

*All aerospace systems are robust to losses and failures. This entry therefore indicates desirable behavior.

Synchronism and whether the application is synchronized to the network are used here to capture how traffic synchronization relates to the application behavior. Synchronized traffic may or may not be synchronized to the application, and in most cases applications will not be synchronized to the network. However, where ultra-low latency is necessary, and an asynchronous boundary between the network and the application cannot be tolerated then it is reasonable, even necessary, to synchronize the application to the network. Examples of this would be fly-by-wire or safety-critical closed-loop control functions. The reader should be aware however that this requirement is sometimes levied because that was how it was implemented previously, and it may not actually be a functional requirement.

Two categories of traffic are generally considered candidates for migration to TSN, namely Ethernet based traffic (ARINC 664 or COTS), and non-Ethernet traffic (ARINC 429/629, Fibre Channel, MIL-STD-1553, IEEE 1394). Current Ethernet systems are asynchronous and have cycle times of 50 ms or higher and will use bounded latency to support safety requirements. Current non-Ethernet systems are often physically partitioned/segmented, can have cycle times of 1 ms or higher, are sensitive to both latency and delay variation and require determinism. As mentioned above, whether these tight latency/jitter requirements are needed on all signals isn't clear, but there are certainly functions that do require this.

Aerospace systems are inherently designed to be tolerant to network frame loss, but eliminating congestion loss should remain an objective. Based on the analysis of existing systems, future TSN-based systems need to address the requirements of both Ethernet and non-Ethernet traffic with the potential evolution to use cases requiring sub-millisecond latency.

7. Required functions for aerospace networks

This clause provides requirements specific to this document and the aerospace use case.

7.1 Time synchronization

Time synchronization is used in aerospace networks to support time-aware functions on end stations and Bridges including enhancements to scheduled traffic and per-stream filtering and policing functions. Synchronized time may be used in aerospace end systems for operation of synchronous applications and time stamping of application payloads to protect and maintain data integrity. This standard specifies time synchronization according to IEEE Std 802.1AS-2020 for conformant components in Clause 5.

Due to the static nature of engineered aerospace networks, the Grandmaster(s) and time distribution tree(s) are predetermined. As a result, aerospace components do not perform best timeTransmitter clock selection or use the associated algorithm (BTCA). Synchronization to external time references (e.g. UTC or TAI) is not necessary for TSN to operate in an aerospace environment but might be required to support system level functions.

It is important for aerospace applications to consider fault-tolerance, including availability and integrity of the synchronizing function to provide reliable and trustworthy time. Mechanisms to support fault-tolerance of time synchronization in IEEE Std 802.1AS-2020 (gPTP) include provisions for multiple time domains, multiple Grandmasters (GM), multiple time distribution trees, and multiple PTP Instances per physical port in Bridges and end stations. The use of these features must be carefully considered by the system designer to meet the fault-tolerance objectives. An aerospace network is expected to tolerate multiple (typically 2) simultaneous arbitrary faults in Bridges, end stations, links, and GMs to maintain availability and integrity of time synchronization. See Annex D for a discussion of fault-tolerant time synchronization for aerospace applications.

7.2 Traffic shaping

The use cases defined in clause 6 require shaping of the traffic at egress ports of Bridges or end stations to meet the latency and packet delay variation (jitter) requirements defined in Table 6-4. Traffic shaping is specified according to the profile being used.

Two traffic shaping methods are applicable to the aerospace use cases:

a) Credit-based shaper algorithm as defined in IEEE Std 802.1Q-2022, clause 8.6.8.2 and
b) Enhancements for scheduled traffic as defined in IEEE Std 802.1Q-2022, clause 8.6.8.4

The credit-based shaper algorithm (CBSA) is used by asynchronous implementations to shape the transmissions of a stream on the basis of the aggregate rate or bandwidth. CBSA does not require network-wide time synchronizations and may be used in aerospace scenarios that do not support time synchronization. CBSA may also be configured in Bridges to shape the flow of unregulated traffic arriving at the Bridge.

The enhancements for scheduled traffic are used by synchronous component implementations to schedule the transmissions of a stream across the network to achieve required latency, jitter, and isolation. A device supporting scheduled traffic is required to also support time synchronization as defined in clause 7.1 since scheduling requires all devices to have the same notion of time. Scheduled traffic may be configured in Bridges to shape and time align asynchronous flows that arrive at the Bridge from non-time-aware components.

Bridge and end station implementations may support both CBSA and scheduled traffic on the same port and users should consider the interaction between the two shapers when evaluating the performance of such an implementation. For example, as described in IEEE Std 802.1Q-2022, clause 8.6.8, the credit for CBSA accumulates only during the time that the gate assigned to the credit-based flow is open, so the CBSA idle slope must be modified based on the duty cycle of the schedule for the assigned output queue.

Implementations must also consider the queuing of frames at end stations and Bridges to achieve the latency, jitter, and isolation requirements for aerospace applications. IEEE Std 802.1Q (8.6.6) provides recommendations for mapping priority to traffic classes depending upon the number of priorities and queues supported by components of the platform. Whilst IEEE Std 802.1Q specifies 8 priority levels, this does not limit the number of queues provided by a Bridge or end station and an implementations could use more than 8 queues when supporting large number of streams, particularly on end stations. Talkers may use a multi-level queuing model as described in IEEE Std 802.1Q, 34.6.1.1 to shape per-stream and per-class traffic. Such implementations may be required to better support stream isolation and are applicable to both CBSA and scheduled traffic.

7.3 Stream isolation

Aerospace use cases require strict isolation between streams to support independence between system functions and prevent faults and failures in one device or application impacting other devices or applications. This is especially important in a scenario where the network converges traffic from sources that are certified to different design assurance levels (mixed-DAL). For example, a Bridge may have two streams that originate from different data sources (talkers), operate at different assurance levels, and arrive at different ingress ports, but are forwarded to the same egress port. This is illustrated in Figure 7-1 where stream 1 and stream 2 originating from end stations #1 and #2, respectively, are forwarded by a Bridge to end station #3. If the Bridge does not identify, filter, police, and monitor each stream individually, faults in one stream could negatively affect the other streams at the output of the Bridge. To support aerospace use cases, this standard requires stream isolation at all conformant Bridges.

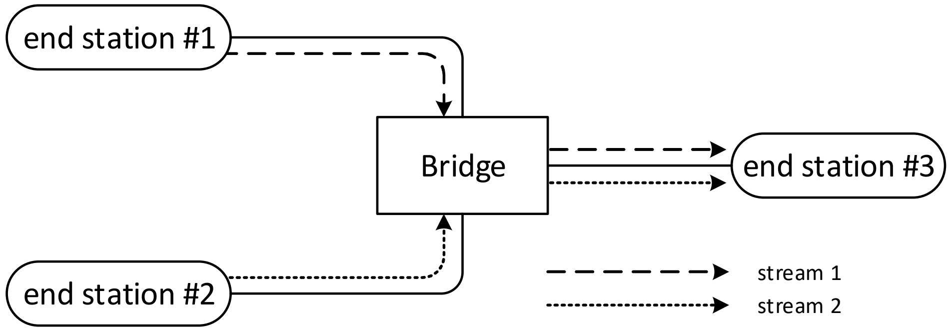

Figure 7-1—Aerospace Stream Isolation

This standard specifies the use of Per-Stream Filtering and Policing (PSFP), defined in IEEE Std 802.1-2022, clause 8.6.5, in Bridges to filter and police streams. PSFP may be used in combination with traffic shaping mechanism to meet the latency and jitter requirements of asynchronous streams. The default behavior for aerospace use cases is to discard frames that do not meet the PSFP criteria assigned to the corresponding stream filter. PSFP requirements for Bridges belonging to the different conformance classes defined in this standard are provided in Clause 5.

Depending on the size, complexity, and design of aerospace network implementations, Bridges will have different requirements for stream isolation, particularly with regards to the supported stream count. While some use cases require very large stream counts per Bridge port, other aerospace use cases involving constrained hardware require low stream count per Bridge port. This standard defines minimum stream count recommendations for both low and high stream count Bridge implementations. Table 7-1 and Table 7-2 specify the minimum number of streams to be identified, filtered, and policed individually at conformant Bridges in an aerospace network.

Table 7-1—Low stream count Bridge recommendations

Number of Ports	Minimum Stream Count
<=4	128
5-8	256
9-12	256
13-18	256
>18	256

Table 7-2—High stream count Bridge recommendations

Number of Ports	Minimum Stream Count
<=4	256
5-8	512
9-12	1024
13-18	2048
>18	>4095

Note: The queuing of frames at an egress ports, as described in IEEE Std. 802.1Q-2022, 8.6.6, may be used to further isolate streams. For example, the priority value of a frame and the mapping of priorities to traffic classes provide additional means of stream isolation. The specific solution for queuing frames to maximize stream isolation is implementation dependent.

7.4 Network redundancy

Aerospace use cases require network redundancy to overcome link and node failures. The standard specifies the use of Frame Replication and Elimination for Reliability (FRER), as defined in IEEE Std 802.1CB-2017 for certain conformant components. FRER provides a flexible solution that supports different redundancy patterns as described in Annex C of IEEE Std 802.1CB-2017. FRER may be used to implement the commonly used aerospace redundancy pattern of dual redundant paths over physically separate networks (e.g. A/B network pattern). Bridge and end station requirements for FRER are described in Clause 5.

FRER enables an application to transmit a single copy of a frame that is replicated by the talker end station or subsequent Bridge for transmission over multiple disjoint paths. At the receiving end station or a preceding Bridge all but one of the copies are discarded, thereby providing seamless redundancy for applications that cannot tolerate packet loss.

Note: FRER can be configured to pass both redundant frames to the receiving application for integrity checks if the use case imposes such a requirement on an implementation.

Note: If an aerospace end system includes an end station and a Bridge, the FRER functions may be implemented in either the end station or the Bridge. In some cases, the FRER functions may be split between the end station and the Bridge.

7.5 Configuration

7.5.1 Aerospace configuration model overview

Due to the safety and assurance requirements, aerospace networks are designed to be engineered networks with static topology best suited for fully centralized configuration model as specified in IEEE Std 802.1Q-2022, clause 46. The topology and stream requirements are derived from higher level system requirements. Therefore, the input data for centralized user configuration (CUC) entity and the centralized network configuration (CNC) component is derived from higher level system interface control documents (ICDs). Aerospace regulatory requirements do not allow direct communication channels between configuration tool entities (CUC, CNC) and network components (Bridges and end stations).

Figure 7-2 depicts the configuration model as specified by this standard. The CUC and the CNC get the information required to generate network and user configuration in the form of static files. And similarly, the CUC and the CNC generate individual file-based device configurations that are loaded into equipment during manufacture or at major service events following an industry or implementation specific process. Aerospace qualified tools are used at each stage of configuration development to verify that configurations are accurate representations of the user requirements with configuration control maintained for individually identifiable items.

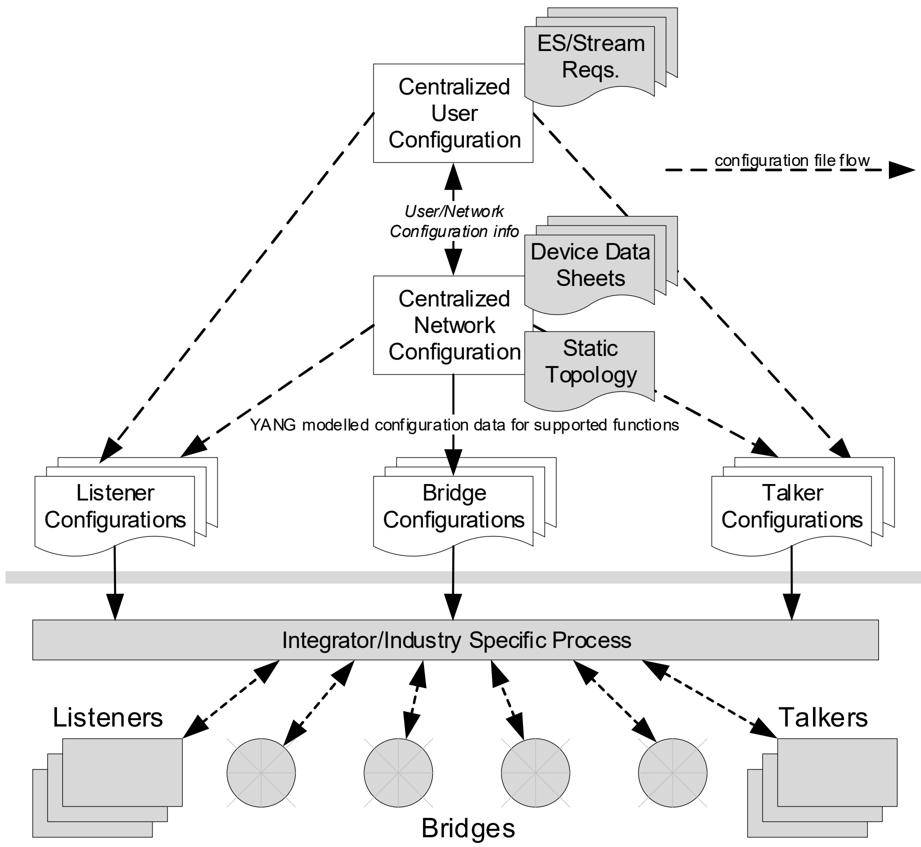

Figure 7-2—Aerospace Configuration Model

Note: The format of input files to CUC and CNC is implementation dependent and out of scope of this standard.

This standard specifies YANG data models to configure TSN functions at conformant end stations and Bridges. The aerospace YANG models used for the TSN features and network entities are specified in Table 7-3.

Note: Aerospace implementations may choose to utilize industry standards like ARINC 665-3 and ARINC 615A to convert the configuration instance data to binary representation and load them on aircraft. This approach is further discussed in Annex C.

Configuration of the end station talkers and listeners requires additional stream centric information (e.g., stream identification, stream tagging and stream shaping parameters) in addition to interface configuration. This standard specifies the use of UNI YANG model as defined in IEEE Std P802.1Qdj to provide the talker and listener configuration data to end stations.

Note: For talker and listener configuration, this standard only specifies the data model with which the instance data is provided to respective end stations. The standard does not define relevant managed objects. Instantiation of the talker/listener configuration on end stations is implementation dependent and out of scope of this standard.

7.5.2 YANG Data Models

This standard selects and specifies the use of YANG data models in aerospace applications from the list of YANG models defined in existing IEEE standards. Only the models used to represent the functionality associated with TSN features on Bridge and end station components are included here as part of the aerospace profile.

Table 7-3—YANG data models

Function	Standard defining the YANG data model	Bridge and/or end station	YANG modules
Time synchronization	IEEE Std 802.1ASdn	Bridge and end station	ietf-yang-types ieee1588-ptp ieee802-dot1as-ptp
Scheduled traffic	IEEE Std 802.1Qcw	Bridge and end station	ieee802-dot1q-sched ieee802-dot1q-sched-bridge
Credit-based shaper (CBS)	IEEE Std 802.1Qdx	Bridge and end station	ieee802-dot1q-cbs ieee802-dot1q-cbs-bridge ieee802-dot1q-cbs-if
Per-Stream Filtering & Policing (PSFP)	IEEE Std 802.1Qcw	Bridge only	ieee802-dot1q-psfp ieee802-dot1q-psfp-bridge
Frame Replications and Elimination for Reliability(FRER)	IEEE Std 802.1CBcv	Bridge and end station	ieee802-dot1cb-frer
Stream identification (Bridge)	IEEE Std 802.1CBcv IEEE Std 802.1CBdb	Bridge only	ieee802-dot1cb-stream-identification ieee802-dot1q-bridge
End station Configuration (Interface/Stream configuration)	IEEE Std 802.1Qdj	End station only	ieee802-dot1dj-tsn-config-uni
Explicit static forwarding	IEEE Std 802.1Q™-2022	Bridge only	ieee802-dot1q-bridge

7.6 Monitoring and management

7.6.1 Overview

Management and monitoring of network equipment and functions is necessary for safe operation of aerospace systems. Clause 7.5 specifies a static configuration model wherein the TSN functions are managed via static configuration files that are loaded on conformant Bridges and end stations prior to the operation of the system. This standard further selects a set of monitoring objects that are required to be maintained and made available by conformant components during operation (flight) for a certifiable solution.

Note: While all management objects for selected TSN features are to be supported as required by IEEE Std 802.1Q, Clause 5, the management objects for configuration (r/w objects) may not be exposed during runtime for safety reasons and may only be accessible via the static configuration files. The management objects defined in 7.6 are monitoring objects (counters) that are to be made available during runtime.

Note: The protocol to access management objects by aircraft management function is outside the scope of this standard.

7.6.2 TSN feature specific monitoring objects

The following sections outline the monitoring objects of the functions outlined in Table 7-3.

7.6.2.1 Required monitoring objects for time synchronization

Managed objects to monitor time synchronization in conformant components are listed in Table 7-4. These objects are defined for each PTP Instance supported by the component.

Table 7-4—Time synchronization managed objects

Name	Data Type	Operations Supported[*]	Reference
clockIdentity	Octet[8]	R	IEEE Std 802.1AS-2020, 8.5.2.2
domainNumber	UInteger8	R	IEEE Std 802.1AS-2020, 10.2.2.1.2
offsetFromMaster	UInteger16	R	IEEE Std 802.1AS-2020, 10.2.10
gmTimebaseIndicator	UInteger16	R	IEEE Std 802.1AS-2020, 9.2.2.3, 9.6.2.3
cumulativeRateRatio	UInteger16	R	IEEE Std 1588, 11.5.3.1.8
grandmasterIdentity	Octet[8]	R	IEEE Std 802.1AS-2020, 8.5.2.2, 14.2.2
portIdentity	UInteger16	R	IEEE Std 802.1AS-2020, 8.5.2.3
asCapable	Boolean	R	IEEE Std 802.1AS-2020, 10.2.5.1
meanLinkDelay	UScaledNs	R	IEEE Std 802.1AS-2020, 10.2.5.8
neighborRateRatio	UInteger32	R	IEEE Std 802.1AS-2020, 10.2.5.7
rxPTPPacketDiscardCount	UInteger32	R	IEEE Std 802.1AS-2020, 14.10.9
syncReceiptTimeoutCount	UInteger32	R	IEEE Std 802.1AS-2020, 14.10.10
pdelayAllowedLostResponsesExceededCount	UInteger32	R	IEEE Std 802.1AS-2020, 14.10.12
cmldsLinkPortNumber	UInteger32	R	IEEE Std 802.1AS-2020, 14.16.2

[*]R = read-only access

7.6.2.2 Required monitoring objects for TAS

Managed objects required to monitor the operation of scheduled traffic in conformant components are listed in Table 7-5. The objects are defined per queue and per port.

Table 7-5—Scheduled traffic managed objects

Name	Data Type	Operations Supported[*]	Reference
TransmissionOverrun	counter	R	12.29.1.1.2

[*]R = read-only access

7.6.2.3 Required monitoring objects for credit-based shaper

No objects are defined to monitor the operation of the credit-based shaper.

7.6.2.4 Required monitoring objects for PSFP

Managed objects required to monitor PSFP stream filtering in conformant components are listed Table 7-6. The objects are defined per stream.

Table 7-6—PSFP stream filter managed objects

Name	Data type	Operations supported*	Reference (IEEE Std 802.1Q)
MatchingFramesCount	counter	R	8.6.5.3
PassingSDUCount	counter	R	8.6.5.3.1
NotPassingSDUCount	counter	R	8.6.5.3.1
PassingFrameCount	counter	R	8.6.5.4
NotPassingFrameCount	counter	R	8.6.5.4
RedFramesCount	counter	R	8.6.5.5

*R = read-only access

Managed objects required to monitor PSFP stream gates in conformant components are listed in Table 7-7. These objects are defined for each stream gate.

Table 7-7—PSFP stream gate managed objects

Name	Data type	Operations supported*	Reference (IEEE Std 802.1Q)
StreamGateClosedDueToInvalidRx	boolean	RW	8.6.5.4
StreamGateClosedDueToOctetsExceeded	boolean	RW	8.6.5.4

*RW = Read/Write access.

Managed objects required to monitor PSFP flow meters traffic in conformant components are listed in Table 7-8. These objects are defined per flow meter.

Table 7-8—PSFP Flow Meter Managed Objects

Name	Data type	Operations supported*	Reference (IEEE Std 802.1Q)
MarkAllFramesRed	boolean	RW	8.6.5.5

*RW = Read/Write access.

7.6.2.5 Required monitoring objects for FRER

Managed objects required to monitor the operation of FRER in conformant components are listed in Table 7-9 and in Table 7-10. These objects are defined per-port and per-stream per-port respectively.

Table 7-9—IEEE Std 802.1CB, FRER, Per-Port Managed Objects

Name	Data type	Operations supported*	Reference (IEEE Std 802.1CB)
frerCpSeqRcvyPassedPackets	counter	R	10.9.1
frerCpSeqRcvyDiscardPackets	counter	R	10.9.2
frerCpSeqEncErroredPackets	counter	R	10.9.3

*R = read-only access.

Table 7-10—IEEE Std 802.1CB, FRER, per-stream, per-port managed objects

Name	Data type	Operations supported*	Reference (IEEE Std 802.1CB)
frerCpsSeqGenResets	counter	R	10.8.2
frerCpsSeqRcvyOutOfOrderPackets	counter	R	10.8.3
frerCpsSeqRcvyRoguePackets	counter	R	10.8.4
frerCpsSeqRcvyPassedPackets	counter	R	10.8.5
frerCpsSeqRcvyDiscardedPackets	counter	R	10.8.6
frerCpsSeqRcvyLostPackets	counter	R	10.8.7
frerCpsSeqRcvyTaglessPackets	counter	R	10.8.8
frerCpsSeqRcvyResets	counter	R	10.8.9
frerCpsSeqRcvyLatentErrorResets	counter	R	10.8.10
frerCpsSeqEncErroredPackets	counter	R	10.8.11

*R = read-only access.

Annex A

(normative)

PCS proforma—IEEE Std 802.1DP Aerospace TSN Networking[10]

A.1 Introduction

The supplier of a protocol implementation that is claimed to conform to this standard shall complete the following 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 specified in Standard X to show that the implementation is conformant; however, the tables in this document will only further refine those elements of conformance to Standard X where particular answers are required for the profiles specified here.

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

a) By the protocol implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight.
b) By the 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) By the 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) By a 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

[10] *Copyright release for PCS proformas:* Users of this standard may freely reproduce the PCS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PCS.

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 with reference or references to the material that specifies the item in the main body of this standard in the third column. The forth column provides additional values or comments to support the conformance questions. The fifth column records the status of the item—whether support is mandatory, optional, or conditional: see also A.3.4. The sixth 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” 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 below, 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.4 PCS proforma for IEEE Std 802.1DP—Aerospace TSN Networking

A.4.1 Implementation identification

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	
NOTE 1—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 2—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

Identification of protocol specification	IEEE Std 802.1DP-<year>, IEEE Standard for Time-Sensitive Networking for Aerospace Ethernet Communications
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 is not conformant).	No [ ] Yes [ ]

Date of Statement	

A.4.3 Implementation summary

The following table is used to indicate the type of component that the PCS describes. A component may support multiple profiles, either simultaneously or independently, and this table should be used to indicate all profiles supported by the component.

Item	Feature	Subclause	Value/Comment	Status	Support
AT1-BC	If the implementation supports asynchronous Type 1 Bridge component functions, mark "Yes" and complete Annex A.5.1* and Annex A.5.2	5.4.1, 5.5.1, 5.4.2, 5.5.2		O	Yes [ ] No [ ]
AT2-BC	If the implementation supports asynchronous Type 2 Bridge component functions, mark "Yes" and complete Annex A.5.1* and Annex A.5.3	5.4.1, 5.5.1, 5.4.3, 5.5.3		O	Yes [ ] No [ ]
ST1-BC	If the implementation supports synchronous Type 1 Bridge component functions, mark "Yes" and complete Annex A.5.1* and Annex A.5.4	5.4.1, 5.5.1, 5.4.4, 5.5.4		O	Yes [ ] No [ ]
ST2-BC	If the implementation supports asynchronous Type 2Bridge component functions, mark "Yes" and complete Annex A.5.1* and Annex A.5.4	5.4.1, 5.5.1, 5.4.5, 5.5.5		O	Yes [ ] No [ ]
AT1-EC	If the implementation supports asynchronous Type 1 end station component functions, mark "Yes" and complete Annex A.6.1* and Annex A.6.2	5.6.1, 5.7.1, 5.6.2, 5.7.2		O	Yes [ ] No [ ]
AT2-EC	If the implementation supports asynchronous Type 2 end station component functions, mark "Yes" and complete Annex A.6.1* and Annex A.6.3	5.6.1, 5.7.1, 5.6.3, 5.7.3		O	Yes [ ] No [ ]
ST1-EC	If the implementation supports synchronous Type 1 end station component functions, mark "Yes" and complete Annex A.6.1* and Annex A.6.4	5.6.1, 5.7.1, 5.6.4, 5.7.4		O	Yes [ ] No [ ]
ST2-EC	If the implementation supports synchronous Type 2 end station component functions, mark "Yes" and complete Annex A.6.1* and Annex A.6.5	5.6.1, 5.7.1, 5.6.5, 5.7.5		O	Yes [ ] No [ ]

* If a component supports multiple profiles then the appropriate common component conformance statement need only be completed once.

Protocol implementations for aerospace onboard Ethernet communications may support either or both Bridge and end station protocol features with asynchronous and/or synchronous capabilities and Type 1 or Type 2 capability profiles. PCS proformas are provided here for all capabilities described in Clause 5, to be complete for each implementation supporting aerospace onboard Ethernet networks.

A.5 Bridge component implementations

A.5.1 Common Bridge component capabilities

The following table describes common bridge component requirements and options.

Item	Feature	Subclause	Comment	Status	Support
BC-1	Supports VLAN Bridge requirements?	5.4.1, a		M	Yes [ ]
BC-2	Supports C-VLANs requirements?	5.4.1, b		M	Yes [ ]
BC-3	FDB supports static and dynamic VLAN registration entries?	5.4.1, c	Indicate how many static entries supported.	M	Yes [ ] Qty. [ ]
BC-4	Supports the strict priority algorithm for transmission selection on each port for each traffic class?	5.4.1, d		M	Yes [ ]
BC-5	Supports stream identification for FRER on all ports for at least 2 traffic classes?	5.4.1, e		M	Yes [ ]
BC-6	Supports Per-Stream Filtering and Policing (PSFP)?	5.4.1, f	Supports maximum SDU size filtering, supports flow metering, supports monitoring for PSFP.	M	Yes [ ]
BC-7	Supports minimum number of stream identification and filtering entries?	5.4.1, g	per Table 7-1	M	Yes [ ]
BC-8	Supports bridge management entities for configuration of Bridge functions?	5.4.1, h	per 7.5	M	Yes [ ]
BC-9	Supports translation of VLAN identifiers	5.5.1, a	Using one or more of the suggested means.	O	Yes [ ] No [ ]

A.5.2 Asynchronous Type 1 Bridge component capabilities

Item	Feature	Subclause	Status	Support
AT1-BC-1	Supports all common Bridge component requirements?	5.4.2, a	AT1-BC:M	Yes [ ]
AT1-BC-2	Supports at least four traffic queues?	5.4.2, b	AT1-BC:M	Yes [ ]
AT1-BC-3	Supports operation of the credit-based shaper algorithm?	5.5.2, a	AT1-BC:O	Yes [ ] No [ ]
AT1-BC-4	Supports at least eight traffic queues?	5.5.2, b	AT1-BC:O	

A.5.3 Asynchronous Type 2 Bridge component capabilities

Item	Feature	Subclause	Status	Support
AT2-BC-1	Supports all asynchronous Type 1 Bridge component requirements?	5.4.3, a	AT2-BC:M	Yes [ ]
AT2-BC-2	Supports FRER?	5.4.3, b	AT2-BC:M	Yes [ ]
AT2-BC-3	Supports monitoring for FRER?	5.4.3, c	AT2-BC:M	Yes [ ]
AT2-BC-4	Supports operation of the credit-based shaper algorithm on all ports for at least 2 traffic classes?	5.4.3, d	AT2-BC:M	Yes [ ]
AT2-BC-5	Supports at least eight traffic queues?	5.5.3, a	AT2-BC:O	Yes [ ] No [ ]
AT2-BC-6	Supports active destination MAC and VLAN stream identification functions?	5.5.3, b	AT2-BC:O	Yes [ ] No [ ]

A.5.4 Synchronous Type 1 Bridge component capabilities

Item	Feature	Subclause	Status	Support
ST1-BC-1	Supports all common Bridge component requirements?	5.4.4, a	ST1-BC:M	Yes [ ]
ST1-BC-2	Supports at least eight traffic queues?	5.4.4, b	ST1-BC:M	Yes [ ]
ST1-BC-3	Supports at least 2 PTP Instances on all physical ports?	5.4.4, c	ST1-BC:M	Yes [ ]
ST1-BC-4	Supports external port configuration capability on all ports?	5.4.4, d	ST1-BC:M	Yes [ ]
ST1-BC-5	Supports PSFP stream gating?	5.4.4, e	ST1-BC:M	Yes [ ]
ST1-BC-6	Supports enhancements for scheduled traffic on all ports?	5.4.4, f	ST1-BC:M	Yes [ ]
ST1-BC-7	Supports the state machines scheduled traffic?	5.4.4, g	ST1-BC:M	Yes [ ]
ST1-BC-8	Supports monitoring for scheduled traffic?	5.4.4, h	ST1-BC:M	Yes [ ]
ST1-BC-9	Supports stream gating for PSFP?	5.4.4, i	ST1-BC:M	Yes [ ]
ST1-BC-10	Supports operation of the credit-based shaper algorithm on all ports and for all traffic classes?	5.5.4, a	ST1-BC:O	Yes [ ] No [ ]
ST1-BC-11	Supports at least 3 PTP Instances?	5.5.4, b	ST1-BC:O	Yes [ ] No [ ]

A.5.5 Synchronous Type 2 Bridge component capabilities

Item	Feature	Subclause	Status	Support
ST2-BC-1	Supports all synchronous Type 1 Bridge component requirements?	5.4.5, a	ST2-BC:M	Yes [ ]
ST2-BC-2	Supports at least 3 PTP Instances on all physical ports?	5.4.5, b	ST2-BC:M	Yes [ ]
ST2-BC-3	Supports FRER functions?	5.4.5, c	ST2-BC:M	Yes [ ]

A.5.5 Synchronous Type 2 Bridge component capabilities *(continued)*

Item	Feature	Subclause	Status	Support
ST2-BC-4	Supports monitoring for FRER?	5.4.5, d	ST2-BC:M	Yes [ ]
ST2-BC-5	Supports operation of the credit-based shaper algorithm on all ports for at least 2 traffic classes?	5.4.5, e	ST2-BC:M	Yes [ ]
ST2-BC-6	Supports active destination MAC and VLAN stream identification functions?	5.5.5, a	ST2-BC:O	Yes [ ] No [ ]

A.6 End station component implementations

A.6.1 Common end station component capabilities

The following table describes common end station component requirements and options.

Item	Feature	Subclause	Comment	Status	Support
EC-1	Supports the strict priority transmission algorithm on all ports for at least 2 traffic classes?	5.6.1, a		M	Yes [ ]
EC-2	Supports operation of the credit-based shaper algorithm on all ports for at least 2 traffic classes?	5.6.1, b		M	Yes [ ]
EC-3	Supports YANG configuration management entities?	5.6.1, c		M	Yes [ ]
EC-4	Supports use of customer VLAN identifiers?	5.7.1, a		O	Yes [ ] No [ ]
EC-5	Supports the use of per-stream VLAN identifiers and PCP?	5.7.1, b		O	Yes [ ] No [ ]
EC-6	Supports at least eight traffic queues?	5.7.1, c		O	Yes [ ] No [ ]

Separate tables are included for Asynchronous and Synchronous, Type 1 and Type 2 end station implementations. Suppliers should complete the PCS tables appropriate to the implementation they are supplying.

A.6.2 Asynchronous Type 1 end station capabilities

Item	Feature	Subclause	Status	Support
AT1-EC-1	Supports all common end station component requirements	5.6.2, a	AT1-EC:M	Yes [ ]

A.6.3 Asynchronous Type 2 end station capabilities

Item	Feature	Subclause	Status	Support
AT2-EC-1	Supports all asynchronous Type 1 end station component requirements	5.6.3, a	AT2-EC:M	Yes [ ]
AT2-EC-2	Supports FRER talker behavior	5.6.3, b	AT2-EC:M	Yes [ ]
AT2-EC-3	Supports FRER listener behavior	5.6.3, c	AT2-EC:M	Yes [ ]
AT2-EC-4	Supports monitoring of FRER	5.6.3, d	AT2-EC:M	Yes [ ]
AT2-EC-5	Supports operation of the per-stream credit-based shaper algorithm for more than one stream?	5.7.3, a	AT2-EC:O	Yes [ ] No [ ]
AT2-EC-6	Supports the FRER stream splitting function on more than one port and for more than one compound stream?	5.7.3, b	AT2-EC:O	Yes [ ] No [ ]
AT2-EC-7	Supports FRER talker behavior on more than one port?	5.7.3, c	AT2-EC:O	Yes [ ] No [ ]

A.6.3 Asynchronous Type 2 end station capabilities *(continued)*

Item	Feature	Subclause	Status	Support
AT2-EC-8	Supports FRER talker behavior for more than one compound stream?	5.7.3, d	AT2-EC:O	Yes [ ] No [ ]
AT2-EC-9	Supports FRER listener behavior on more than one port?	5.7.3, e	AT2-EC:O	Yes [ ] No [ ]
AT2-EC-10	Supports FRER listener behavior for more than 1 compound stream?	5.7.3, f	AT2-EC:O	Yes [ ] No [ ]

A.6.4 Synchronous Type 1 end station capabilities

Item	Feature	Subclause	Status	Support
ST1-EC-1	Supports all common end station component requirements?	5.6.4, a	ST1-EC:M	Yes [ ]
ST1-EC-2	Supports at least 2 PTP Instances on all physical ports?	5.6.4, b	ST1-EC:M	Yes [ ]
ST1-EC-3	Supports external port configuration capability on all ports?	5.6.4, c	ST1-EC:M	Yes [ ]
ST1-EC-4	Supports end station enhancements for scheduled traffic?	5.6.4, d	ST1-EC:M	Yes [ ]
ST1-EC-5	Supports the monitoring requirements of scheduled traffic?	5.6.4, e	ST1-EC:M	Yes [ ]
ST1-EC-6	Supports at least 3 PTP Instances on all physical ports?	5.7.4, a	ST1-EC:O	Yes [ ] No [ ]

A.6.5 Synchronous Type 2 end station capabilities

Item	Feature	Subclause	Status	Support
ST2-EC-1	Supports all synchronous Type 1 end station component requirements?	5.6.5, a	ST2-EC:M	Yes [ ]
ST2-EC-2	Supports at least 3 PTP Instances on all physical ports?	5.6.5, b	ST2-EC:M	Yes [ ]
ST2-EC-3	Supports FRER talker behavior?	5.6.5, c	ST2-EC:M	Yes [ ]
ST2-EC-4	Supports FRER listener behavior?	5.6.5, d	ST2-EC:M	Yes [ ]
ST2-EC-5	Supports monitoring of FRER?	5.6.5, e	ST2-EC:M	Yes [ ]
ST2-EC-6	Supports the FRER stream splitting function on more than one port and for more than one compound stream?	5.7.5, a	ST2-EC:O	Yes [ ] No [ ]
ST2-EC-7	Supports FRER talker behavior on more than one port?	5.7.5, b	ST2-EC:O	Yes [ ] No [ ]
ST2-EC-8	Supports FRER talker behavior for more than one compound stream?	5.7.5, c	ST2-EC:O	Yes [ ] No [ ]
ST2-EC-9	Supports FRER listener behavior on more than one port?	5.7.5, d	ST2-EC:O	Yes [ ] No [ ]
ST2-EC-10	Supports FRER listener behavior for more than 1 compound stream?	5.7.5, e	ST2-EC:O	Yes [ ] No [ ]

Annex B

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] ARINC Specification 664 part 7, Avionics Full-Duplex Switched Ethernet Network.

[B2] Asynchronous Transfer Mode (ATM): A collection of equipment and standards used for telecommunications and data transfer, https://www.itu.int/ITU-T/ and https://www.broadband-forum.org.

[B3] Jabbar-et-al, Summary of Aerospace Use Cases, https://www.ieee802.org/1/files/public/docs2021/dp-Jabbar-Aerospace-UseCase-Summary-0521-v01.pdf

[B4] Jabbar-et-al, Aerospace Traffic Characterization, https://www.ieee802.org/1/files/public/docs2021/dp-Jabbar-et-all-Aerospace-Traffic-Characterization-0421-v02.pdf.

[B5] RTCA DO-178C, Software Considerations in Airborne Systems and Equipment Certification

[B6] RTCA DO-254, Design Assurance Guidance for Airborne Electronic Hardware

[B7] ARP4754A/B, Guidelines for Development of Civil Aircraft and Systems

[B8] ARP4761/A, Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment

Annex C

(informative)

Example Aerospace Configuration

C.1 Introduction

In the highly regulated aerospace industry, the generation of complex network configurations is required to be traceable to system level requirements to ensure that the system behavior is that which was intended and that unintended behavior is eliminated. TSN network configurations are no exception to this and system integrators will often rely on tooling to develop the configurations used in the equipment that makes up the system for which TSN is being used.

aerospace applications use a fully centralized configuration model to define an engineered static network topology. This profile for TSN aerospace communications does not specify the process by which configurations are loaded into the network but leaves that to the integrator to define. This Annex is intended to provide an example for how this might be achieved in a typical commercial aerospace application.

C.2 Fully Centralized Aerospace Configuration

An example for an aerospace configuration model is provided in Figure C-1 and explained below. In this example it is expected that a modeling tool is used to design the network topology and streams required by the application. Depending upon the complexity of the required system and on the expectation for through-life support and modification, this could be as simple as a series of spreadsheets or a sophisticated model-based engineering tool capable of supporting complex analysis plug-ins. The main point being that the configuration process can be maintained for the life of the system controlled

TSN standards make no mention of how a system might be configured to perform a specified user function but instead provide the building blocks from which a variety of systems can be built. It is then up to users and integrators to decide how these standards are combined to implement the desired functionality. In an aerospace application it is expected that system level requirements will be defined to support safety assessments and that these will require consistency and performance checks to be made on the output of the configuration step.

Whilst TSN configurations will use YANG configuration models, 7.5.2, aerospace equipment is expected to use vendor-specific binary configurations that are generated from the YANG models. Vendor supplied configuration tools are therefore expected to be supplied with equipment that performs translation from YANG models to vendor-specific binary data and that performs verification on the output to show that it matches the configuration requirements described in the YANG model. The expectation would then be that the configuration tool and verifier are qualified tools following guidance provided by DO-178C [B5].

Once the vendor-specific binary configuration data has been generated, this data can then be loaded into equipment that makes up the system to configure the Bridges and end stations that constitute the time-sensitive network. Aerospace norms suggest here that ARINC specifications are used to define how this is performed, in particular with data provided as loadable software according to ARINC 665 and loaded using an ARINC 615-A compliant data loader (Bibliography additions needed).

The topology and configurations are developed from requirements that represent the required system behavior. A design modeling tool is used to generate all input to centralized configuration models (CUC & CNC) from which individual device configurations are derived. Consistent with aerospace practice, no direct communications occur between the CUC/CNC and Bridges or end stations. Instead, individual file-based device configurations are created and loaded into equipment during manufacture or at major service events. Aerospace qualified tools are used at each stage of configuration development to verify that configurations are accurate representations of the user requirements with configuration control maintained for individually identifiable items. Figure C-1 depicts the configuration model specified by the aerospace profile. Physical links are implied between talkers, listeners and bridges but are excluded from the figure for clarity.

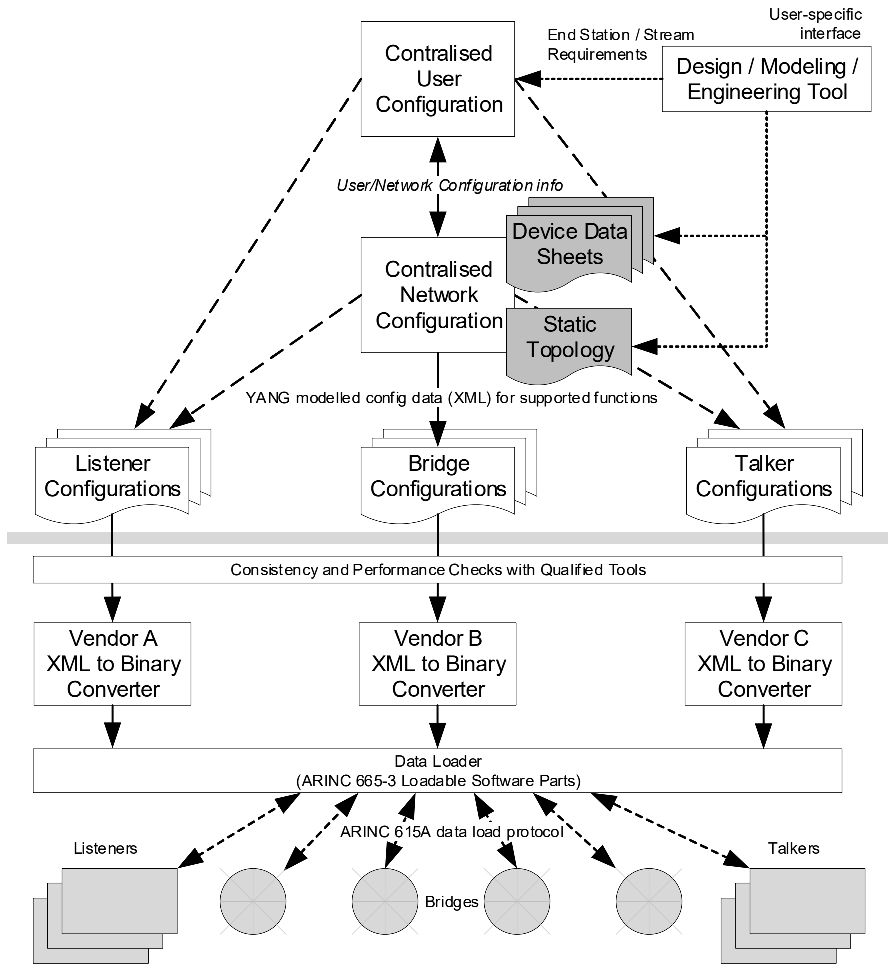

Figure C-1—Aerospace Configuration Model Example

Annex D

(informative)

Time Synchronization for Aerospace Systems

D.1 Introduction

This Annex provides example patterns for time synchronization in aerospace systems.

Synchronous aerospace systems, i.e. those conforming the synchronous TSN Aerospace profile, are expected to tolerate multiple (typically 2) simultaneous arbitrary faults in end stations, Bridges, links, and GMs to maintain availability and integrity of time synchronization,

Fault-tolerance, or availability, and integrity address the reliable and accurate transmission of time values and the associated sync and follow-up messages in the presence of arbitrary faults in the network (link, Bridge, end station, and GM). Thus, under fault conditions, a correctly operating end station is expected to maintain a target maximum time error relative to the correctly operating GM. If unable to maintain the max time error, the correctly operating end station will detect an erroneous time sync state. To support this, it is expected that multiple clock domains, introduced in IEEE Std 802.1AS, are configured and managed in the network.

To achieve the required level of fault-tolerance for the aerospace use case a Fault-Tolerant Timing Module (FTTM) is necessary, to provide fault-tolerance amongst available PTP Instances and time values as a time-aware higher level application, in accordance with IEEE Std 802.1AS-2020, Clause 9. The FTTM is defined in P802.1ASec (tentative reference) and would be supported by Bridges and end stations conformant to the synchronous profile of this standard.