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Introduction

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For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



65C/1037/CD

COMMITTEE DRAFT (CD)

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France

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Ms Valérie DEMASSIEUX

OF INTEREST TO THE FOLLOWING COMMITTEES:

TC 57

PROPOSED HORIZONTAL STANDARD:

☐

Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

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☐ ENVIRONMENT

☐ QUALITY ASSURANCE

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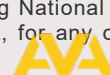
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TITLE:

Time-sensitive networking profile for industrial automation

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Time-Sensitive Networking Profile for Industrial Automation

FOREWORD

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International Standard IEC/IEEE 60802 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation, in cooperation with IEEE 802.1: Higher Layer LAN Protocols Working Group of IEEE 802: LAN/MAN Standards Committee of the IEEE computer society¹, under the IEC/IEEE Dual Logo Agreement.

It is published as an IEC/IEEE dual logo standard.

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
65C/XX/FDIS	65C/XX/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The National Committees are requested to note that for this document the stability date is 2024.

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¹ A list of IEEE participants can be found at the following URL: (to be provided prior to publication).

INTRODUCTION

Editor's Note: This profile has been drafted per the IEC style guide. The use of introductory boilerplate text, editorial conventions and clause numbering may differ from those outlined in the IEEE style guide.

For the convenience of the reviewer, references to the IEC-IEEE cooperation process and to the IEC organization and style guidelines are listed below:

IEC-IEEE 60802 Joint Project Cooperation Process:

<http://www.ieee802.org/1/files/public/docs2018/admin-IEC-IEEE-JWG-cooperation-process-0118.pdf>

IEC organization:

<http://www.iec.ch/>

Home of the IEC organization of the Joint Project IEC/IEEE 60802 is: IEC 65C/MT9.PT60802:

https://www.iec.ch/dyn/www/f?p=103:14:16714897859893:::FSP_ORG_ID,FSP_LANG_ID:21073,25

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<http://www.iec.ch/standardsdev/resources/draftingpublications/>

Reference material:

http://www.iec.ch/members_experts/refdocs/

ISO/IEC Directives, Part 2:2018

edition 8.0 (2018-05)

Principles and rules for the structure and drafting of ISO and IEC documents:

http://www.iec.ch/members_experts/refdocs/iec/isoiecdir-2%7Bed7.0%7Den.pdf

ISO/IEC Directives, Part 1:2019 + IEC Supplement:2019

edition 15.0 (2019-05) consolidated with IEC Supplement, edition 13.0 (2019-05)

contains the redline version Procedures for the technical work - Procedures specific to IEC:

https://www.iec.ch/members_experts/refdocs/iec/isoiecdir1%7Bed15.0%7Den.pdf

This document defines Time-Sensitive Networking profiles for industrial automation. The profiles select features, options, configurations, defaults, protocols, and procedures of bridges, end stations, and LANs to build industrial automation networks.

These profiles meet the industrial automation market objective of converging Operations Technology (OT) and Information Technology (IT) networks by defining a common, standardized network infrastructure. This objective is accomplished by taking advantage of the improvements that Time-Sensitive Networking provides to IEEE 802.1 and IEEE 802.3 standard Ethernet networks by providing guaranteed data transport with bounded low latency, low latency variation, zero congestion loss for critical traffic, and high availability.

These profiles help the convergence of industrial communication networks by only referring to IEEE Std 802.3 and IEEE 802.1 standards to build the lower layers of the communication stack and their management. Furthermore, these profiles allow the coexistence of different data streams between end stations, including data streams as defined in IEC 61784-2, which have different performance characteristics and functional capabilities according to the diverse application requirements. It is understood that some of the Communication Profile Families in IEC 61784-2 need to be modified to ensure compliance to the IEC/IEEE 60802 profile. Such modifications are out of scope for the IEC/IEEE 60802 profile.

IEEE Std 802.3 Ethernet extended with IEEE 802.1 Time-Sensitive Networking technology provides the features required in the field area of industrial communication networks, such as:

- Meeting low latency and latency variation requirements concerning data transmission.
- Efficient exchange of data records on a frequent time period.
- Reliable communications with calculable downtime.
- High availability meeting application requirements.

Time-sensitive networking profile for industrial automation

1 Scope

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

2 Normative references

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

IEC 61784-2, Industrial communication networks — Profiles — Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3.

IEEE Std 802®-2014, IEEE Standard for Local and metropolitan Area Networks: Overview and Architecture.

IEEE Std 802c™-2017, IEEE Standard for Local and metropolitan Area Networks: Overview and Architecture Amendment 2: Local Medium Access Control (MAC) Address Usage.

IEEE Std 802.1QTM-2018, IEEE Standard for Local and metropolitan Area Networks — Bridges and Bridged Networks.

IEEE Std 802.1Qcc™-2018, IEEE Standard for Local and metropolitan Area Networks — Bridges and Bridged Networks Amendment 31: Stream Reservation Protocol (SRP) Enhancements and Performance Improvements.

IEEE Std 802.1AB™-2016, IEEE Standard for Local and metropolitan area networks — Station and Media Access Control Connectivity Discovery

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

IEEE Std 802.1AE™-2018, IEEE Standard for Local and metropolitan area networks — Media Access Control (MAC) Security.

IEEE Std 802.1X™-2010, IEEE Standard for Local and metropolitan area networks — Port-Based Network Access Control.

IEEE Std 802.1AR™-2018, IEEE Standard for Local and metropolitan Area Networks — Secure Device Identity.

IEEE Std 802.1AS-2020, IEEE Draft standard for local and metropolitan area networks — Timing and Synchronization for Time-Sensitive Applications.

IEEE Std 802.3™-2018, IEEE Standard for Ethernet.

IEEE Draft Std P802.3cg, Draft Standard for Ethernet Amendment 4: Physical Layer Specifications and Management Parameters for 10 Mb/s Operation and Associated Power Delivery over a Single Balanced Pair of Conductors.

Editor's Note: Any draft standards will be removed prior to CDV and Sponsor Ballot.

3 Terms, definitions, symbols and abbreviated terms

3.1 General

For the purposes of this document, the terms and definitions given in ITU-T G.781.1, ITU-T G.810, ITU-T G.8260, IEEE 802, IEEE 802.3, IEEE Std 802.1Q-2018, IEEE Std 802.1AS-2020, and the following apply:

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

3.2 List of terms and definitions given in ITU-T G.781.1, ITU-T G.810, ITU-T G.8260, IEEE 802, IEEE Std 802.3-2018, IEEE Std 802.1Q-2018 and IEEE Std 802.1AS-2020

Editor's note: Any standard referenced in the section title but not referenced in the table will be removed prior to CDV and sponsor ballot.

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

Table 1 – List of terms

Term	Source
acquiring mode	ITU-T G.781.1
Bridge	IEEE Std 802.1Q™-2018
Bridge Port	IEEE Std 802.1Q™-2018
Bridged Network	IEEE Std 802.1Q™-2018
Constant time error (cTE)	ITU-T G.8260
Dynamic time error (dTE)	ITU-T G.8260
end station	IEEE Std 802@-2014
Ethernet	IEEE Std 802.3™-2018
fractional frequency offset	IEEE Std 802.1AS-2020
Frame	IEEE Std 802.1Q™-2018
free-run mode	ITU-T G.781.1
Grandmaster Clock	IEEE Std 802.1AS-2020
gPTP Communication Path	IEEE Std 802.1AS-2020
Jitter	ITU-T G.810
LAN	IEEE Std 802@-2014
latency	IEEE Std 802.1Q™-2018
Listener	IEEE Std 802.1Q™-2018
local clock	IEEE Std 802.1AS-2020
locked mode	ITU-T G.781.1
Maximum absolute relative time error (max TER)	ITU-T G.8260
Maximum absolute time error (max TE)	ITU-T G.8260
Port	IEEE Std 802.3™-2018
preemption	IEEE Std 802.1Q™-2018
PTP End Instance	IEEE Std 802.1AS-2020
PTP Link	IEEE Std 802.1AS-2020
PTP Instance	IEEE Std 802.1AS-2020
PTP Relay Instance	IEEE Std 802.1AS-2020

Term	Source
Relative time error (TER)	ITU-T G.8260
station	IEEE Std 802.1Q-2014
Stream	IEEE Std 802.1Q™-2018
synchronized time	IEEE Std 802.1AS-2020
Talker	IEEE Std 802.1Q™-2018
Time error	ITU-T G.8260
time-sensitive stream	IEEE Std 802.1Q™-2018
traffic class	IEEE Std 802.1Q™-2018

324

325 **3.3 TSN-IA defined Terms**326 **3.3.1**327 **application clock**

328 clock used by the application to time events in the application

329 **3.3.2**330 **Application Data Cycle**

331 user-defined time interval required for data-exchange between applications

332 Note 1 to entry: For example: applications for closed loop control.

333

334 **3.3.3**335 **Deadline**

336 application-defined fixed time reference point within the network cycle

337 **3.3.4**338 **external error**339 error introduced in the system by for example receiving time from GPS to synchronize the Clock
340 of the Global Time Grandmaster PTP Instance341 **3.3.5**342 **Global Time**

343 synchronized time in a network that is traceable to a known source

344 **3.3.6**345 **IA-controller**

346 entity that exchanges data with several IA-devices for the purpose of control of a system

347 Note 1 to entry: The primary categories are distributed control system (DCS), programmable logic controller (PLC)
348 and programmable automation controller (PAC).

349

350 **3.3.7**351 **IA-device**

352 entity that exchanges data with an IA-controller for the purpose of control of a system

353 **3.3.8**354 **Isochronous Application**

355 application that is synchronized to the Working Clock that is synchronizing network access

356 **3.3.9**357 **Network Access**

358 action of placing frames on the network or of collecting frames from the network

359 Note 1 to entry: This concept is unrelated to port-based access control as defined in IEEE Std 802.1X-2010.

360

3.3.10**Network Cycle**

user-defined time interval derived from the Working Clock and used to control Network Access

3.3.11**Network Diameter**

longest of all the calculated shortest paths in the network

3.3.12**Non-seamless redundancy**

type of redundancy in which only one of the redundant paths is selected as on-service while the other paths are in stand-by

3.3.13**Redundancy**

existence in a bridge, end station, or LAN of two or more means for performing a required function

3.3.14**Scheduling Cycle**

IA-ME defined time interval during which Talker-Listener pairs exchange cyclic data

3.3.15**Seamless Redundancy**

type of redundancy in which messages are transmitted via two or more maximally divergent paths

3.3.16**Start of cycle trigger**

point in time in the Working Clock time domain, which aligns the understanding of time between application data cycle, scheduling cycle and network cycle

3.3.17**TSN Domain**

set of stations (end stations and/or Bridges), their ports, and the attached LAN's that transmit time-sensitive streams using TSN standards, which include transmission selection algorithms, preemption, time synchronization and enhancements for scheduled traffic and that share a common management mechanism (or "policy engine")

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

3.3.18**Working Clock**

network clock derived from one or more gPTP domains

3.4 Abbreviated terms and acronyms

Editor's Note: This section will be checked and completed prior to CDV and sponsor ballot.

IA	Industrial automation
IA-ME	Industrial Automation Management Entity
TSN-IA	Time Sensitive Networking for Industrial Automation

3.5 Conventions**3.5.1 Principles for (sub) clause selections of referenced documents**

Normative references in Clause 4 are established based upon the following principles:

- a) This document shall explicitly identify which parts (clauses, sub clauses, figures, lists, tables, etc.) of the cited standards apply to this profile.

b) The features of any cited standard that are mandatory (identified by shall), optional (identified by may), prohibited (identified by may not), or not applicable shall be explicitly identified.

c) Additional constraints for features of any cited standard shall be identified.

Editor's Note: This section (3.4.1) is provided for reference only and will be removed prior to CDV and sponsor ballot.

3.5.2 Convention for Capitalizations

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

Throughout this document "bridge" can be used instead of "Bridge", except when

- a) it occurs at the beginning of a sentence or
- b) it is being used as (or part of) a specific term such as "VLAN Bridge" rather than being used to identify bridges (potentially of any type) in general. If "VLAN Bridge" is meant where "Bridge" only is written a change to "VLAN Bridge" would be appropriate.

Editor's note: Any terms listed which are not referenced will be removed prior to CDV and sponsor ballot .

3.5.3 Unit conventions

This document uses

- Gbps for Gb/s and
- Mbps for Mb/s.

4 Overview of TSN in Industrial Automation

4.1 Control loop operation

Industrial network applications are based on three main types of building blocks which may be combined in one IA-device or provided as separate IA-devices interconnected through a suitable communication network.

These basic building blocks are:

- Sensor applications which provide input measurements indicating the state of a parameter being monitored or controlled;
- IA-controller applications which operate on combinations of measurements and external demand settings to develop output requests;
- Actuator applications which implement output requests as physical changes to the process or machine under control, such as a level in a storage tank, the speed of a printing press, or movement of a robot.

NOTE Sensors and actuators are examples of an IA-device.

A control loop is formed when the process or machine responds to the actuator output and produces a new measured value at the sensor. The complete loop is shown in Figure 1 where the application IA-devices are connected as end stations of a TSN infrastructure.

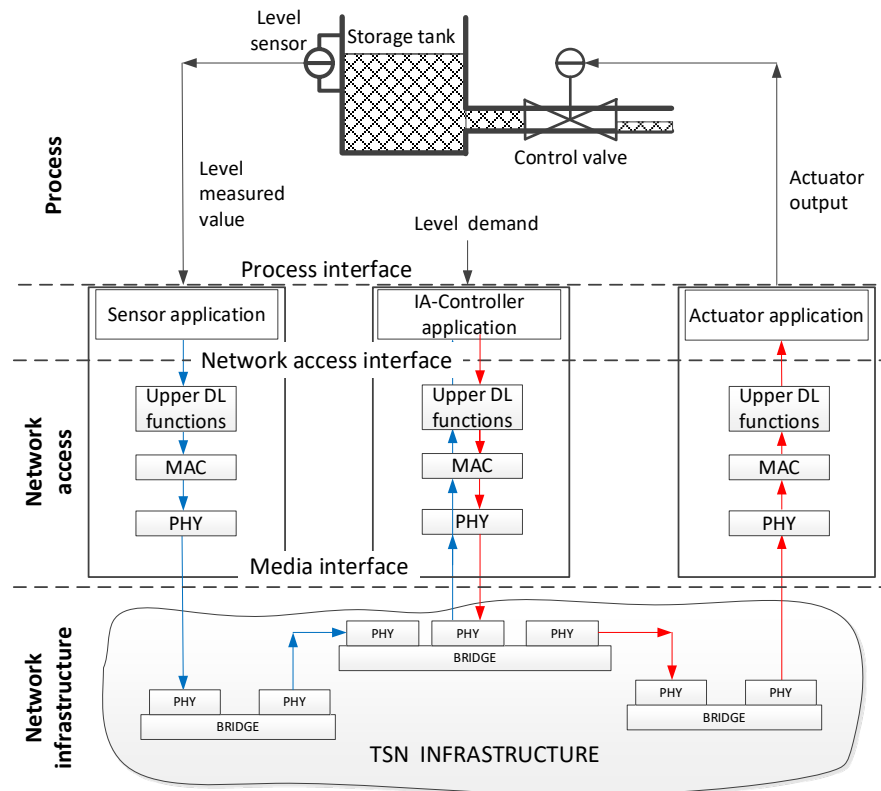


Figure 1 –Data flow in a control loop

In operation, the sensor application samples the measured value and the sampled values are transferred through the network as data packets for the IA-controller to compare with the demand value. After any computational time, the required output is transferred from the IA-controller to the actuator for implementation as a change in the external process.

This sequence repeats continuously as a regular operation using a local or a network time base. For good control, the sequence repetition rate needs to be 5 to 10 times faster than the time constant of the process response.

Control latency, or time delay between the sensor input and actuator output, is a critical factor in all types of control and needs to be minimized and bounded.

Components of the control latency time are shown as levels in Figure 1:

- Application time for sampling, computation and processing within each IA-device. These are IA-device specific and known to the IA-device makers.
- Network access time for data transfer through the Upper Layer DLL, MAC and PHY layers within each IA-device. These are implementation-dependent and can be influenced by the TSN configuration on end stations.
- Network & Bridge scheduling and transfer time through the external TSN network and bridges. These are set by the TSN configuration process which allocates available bandwidth and priorities to various types of application messages.

For a planned installation, engineering tools are needed to calculate the control latency time.

During system operation TSN, management services are needed to measure and report actual latency time at the network access interface. This is essential for diagnostics and checking the performance of an installed network.

4.2 Control Loop Applications

Applications need to have a common understanding of time among each other or with the network if they need to synchronize and sequence events. This is used for things such as synchronizing multiple axes of motion, for timestamping various events. The Working Clock

enables a common understanding of time. If an application doesn't need to use a common understanding of time, it may be executing based on a local timescale.

The Working Clock synchronizes a TSN network using IEEE Std 802.1AS-2020. While bridges propagate the Working Clock, they will only synchronize transmission according to the Working Clock if Enhancements for Scheduled Traffic (IEEE Std 802.1Q-2018) is enabled.

While many traffic types are implemented on an industrial automation system, only a few traffic types require minimized latency and known delivery windows. Examples are isochronous real-time traffic and cyclic real-time traffic.

Isochronous real-time traffic is commonly used for motion control and can have application data cycle times lower than 50 μ s. Isochronous traffic expects the application data cycle to be aligned with the Working Clock. Cyclic traffic is typically used for reading sensors and activating output signals at 1 ms and above.

4.3 Network access

As shown in Table 2, the application and network access can be synchronized to the working clock. In this case, some mechanism is required to align the understanding of time between the application data cycle, the network cycle and the scheduling cycle. This relationship is depicted in Figure 2. In this example, each time-aware, Talker-Listener pair must understand when to exchange data to avoid conflict with other Talker-Listener data exchanges. This scheduling may be accomplished via the applications or via the enhancements for scheduled traffic defined in IEEE Std 802.1Q-2018. Likewise, bridges in the network must schedule gate events that accommodate these schedules. Finally, the application must understand when data is being transferred so that it can then calculate the corresponding outputs for the next application cycle. The start of cycle trigger provides the synchronizing event between application data cycle, the network cycle and the scheduling cycle.

Table 2 – Application Requirements

Level	Isochronous Application		Non-Isochronous Application		
Application	Synchronized to network access		Synchronized to local timescale		
Network access	Synchronized to Working Clock				Synchronized to local timescale
Network/Bridges	Synchronized to Working Clock	Free running	Synchronized to Working Clock	Free running	Free running

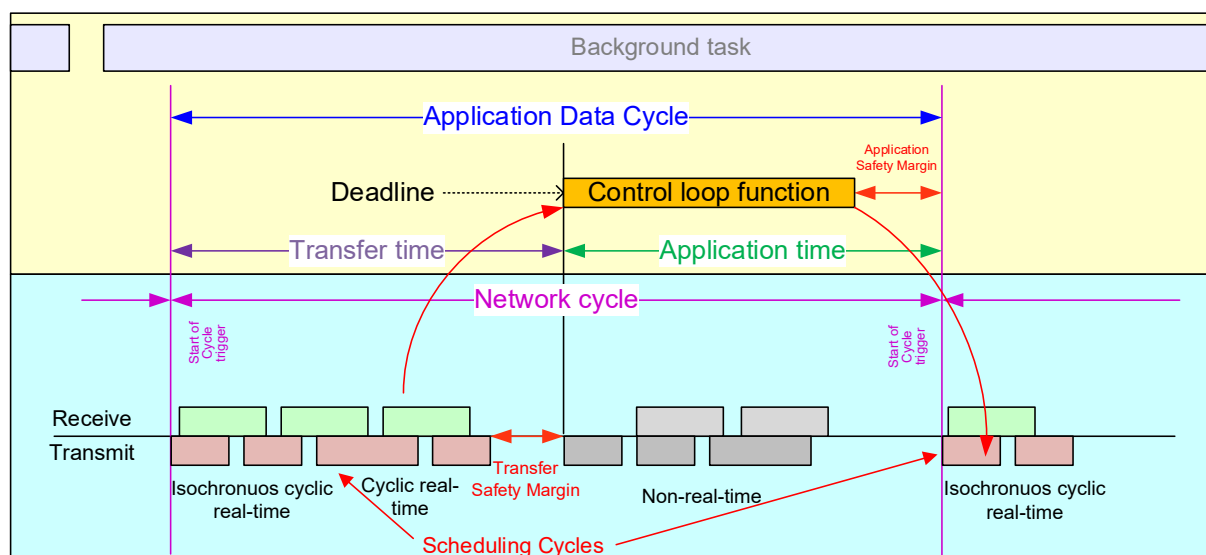


Figure 2 – Isochronous network Access

4.4 Mechanisms that can be used to meet Control Loop Latency Requirements

Meeting latency requirements on a network can be accomplished in multiple ways. Some of those methods are:

1. Define and test all possible application combinations
2. Overprovisioning the network
3. Providing scheduled time slots for each application to transmit on the network
4. Preempting lower priority traffic
5. Providing scheduled time slots for certain traffic classes
6. Synchronizing network access
7. Simulating the traffic load of specific implementations ahead of time
8. Using Enhancements for Cyclic Queuing and Forwarding

Preemption is defined in IEEE Std 802.1Q-2018 and IEEE Std 802.3-2018.

Reserving time on the network for certain traffic types can be done through specific implementations of Enhancements for Scheduled Traffic (IEEE Std 802.1Q-2018). A network cycle needs to be defined for this to work. The network cycle is a multiple period of the application data cycles that are traversing the network. Once that cycle time is defined, portions of that cycle time can either be allocated to streams or classes of streams.

When a single application is implemented on a network, that application can sequence the communications of the IA-controller, sensors and actuators. When multiple applications share the same network, those applications need to validate that the network will always meet their latency requirements. This can be accomplished by synchronizing Network Access. This is a method for coordinating transmission of all the traffic that shares a Network to validate all application requirements can be met and increasing utilization.

Creating a digital model of network traffic ahead of time will guarantee that a solution will work and can allow network access to be synchronized.

4.5 Integration of TSN in Industrial Automation

This subclause describes a vision for how TSN can be integrated into an industrial automation network taking into account requirements for flexibility and the natural evolution of device requirements over the lifecycle of an industrial device.

The workflow of a time-sensitive industrial network can start before device acquisition or wiring ever takes place. This workflow can scale to fit the requirements of both machine builders and end integrators. Initially, a model of a logical grouping of applications for the network scope, otherwise known as things, that share infrastructure devices or need to talk to one another in a time sensitive manner is developed. This model is known as a TSN domain. A virtual simulation of the applications running over a TSN domain is created that could be from a configuration file from a single application, configuration of multiple applications that traverse multiple TSN domains or as complex as a full factory floor with input from numerous parties.

Offline TSN Data sheets are provided and can serve two functions. First, they can convey TSN functionality of complaint infrastructure. Second, they can act as a method of conveying network access requirements to network infrastructure.

The network level model has the requirement of conveying requirements for network access to a centralized network controller (IA-ME) function in terms of number of streams, payload size, frame interval and jitter tolerance. This data can be conveyed via data sheets if the application programming function(s) and IA-ME function are in two different pieces of software or devices.

The IA-ME function will also take as an input the network topology design if it is created as a separate exercise for a network that is not yet in place, or via crawling an existing network with

techniques such as LLDP. TSN Data sheets for compliant infrastructure are provided to enumerate TSN capabilities of offline infrastructure while IEEE Std 802.1Q, IEEE Std 802.1AS IEEE Std 802.3 managed objects will provide TSN capabilities of online infrastructure. Accepted network topology can be limited to the design rather than the crawled topology as an option.

The IA-ME function will combine the application requirements with the network capabilities and perform network calculus, scheduling, or both to validate the TSN domain can meet the requirements of all applications defined at calculation time. If the network is unable to meet the needs of all applications the engineering interface to the IA-ME function will prompt the user where issues need to be addressed.

Provided a TSN domain passes validation, network configuration is pushed down from the IA-ME function to the infrastructure and end stations through managed objects. The infrastructure and application level end stations will synchronize to the selected grandmaster clock and provide an indication that they have synchronized. A user will be able to then run their application(s) at will and the network configuration will be saved to non-volatile memory of infrastructure devices. The IA-ME function can go away in the case of static configurations, or a subset of its capabilities can stay running at all times to handle network or application changes.

Any streams that go out of the TSN domain under consideration is modeled as an application requirement TSN data sheet for input to the next TSN domain if directly connected without brownfield infrastructure in between.

4.6 Industrial Traffic Types

4.6.1 General

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

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

Table 3 – Industrial automation traffic types summary

Traffic type name	Periodicity	Data delivery requirements	Synchronized to network cycle	Criticality
Isochronous	Cyclic/periodic	Deadline	Yes	High
Cyclic-Synchronous	Cyclic/periodic	Latency	Yes	High
Cyclic-Asynchronous	Cyclic/periodic	Latency	No	High
Alarms and Events	Acyclic/sporadic	Latency	No	High
Configuration & Diagnostics	Acyclic/sporadic	Bandwidth	No	Medium
Network Control	Cyclic/periodic	Bandwidth	No	High
Best Effort	Acyclic/sporadic	None	No	Low
Video	Acyclic/sporadic	Latency	No	Low