Draft for Public Comment

Form 36

DPC: 20/30423044 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000
Fax: +44 (0)20 8996 7400
www.bsigroup.com

Date: 26 June 2020
Origin: International

Latest date for receipt of comments: 15 July 2020

Project No. 2017/02526

Responsible committee: GEL/65 Measurement and control

Interested committees:

Title: Draft BS EN IEC 60802 Time-sensitive networking profile for industrial automation.

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

i) has any issues related to 3rd party IPR, patent or copyright
ii) affects other national standard(s)
iii) requires additional national guidance or information

WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD. THIS DRAFT IS NOT CURRENT BEYOND 15 July 2020

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

No copying is allowed, in any form, without prior written permission from BSI except as permitted under the Copyright, Designs and Patent Act 1988 or for circulation within a nominating organization for briefing purposes. Electronic circulation is limited to dissemination by e-mail within such an organization by committee members.

Further copies of this draft may be purchased from BSI Shop http://shop.bsigroup.com or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com. British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from https://standardsdevelopment.bsigroup.com/.

Responsible Committee Secretary: Jasnam Channe (BSI)
Direct tel:
E-mail: jasnam.channe@bsigroup.com

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

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.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at **https://standardsdevelopment.bsigroup.com/**. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx

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.	

Documents
Document Sharing Hub

Full document details: 20/30423044 DC

65C/1037/CD

COMMITTEE DRAFT (CD)

PROJECT NUMBER: **IEC 60802 ED1**	
DATE OF CIRCULATION: **2020-06-19**	CLOSING DATE FOR COMMENTS: **2020-08-14**
SUPERSEDES DOCUMENTS: **65C/987/CD, 65C/994A/CC**	

IEC SC 65C : INDUSTRIAL NETWORKS	
SECRETARIAT: France	SECRETARY: 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: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

TITLE:

Time-sensitive networking profile for industrial automation

NOTE FROM TC/SC OFFICERS:

Copyright © 2020 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

AVA Documents Document Sharing Hub

Full document details: 20/30423044 DC

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms, definitions, symbols and abbreviated terms 10
3.1 General 10
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 10
3.3 TSN-IA defined Terms 11
3.4 Abbreviated terms and acronyms 12
3.5 Conventions 12
3.5.1 Principles for (sub) clause selections of referenced documents 12
3.5.2 Convention for Capitalizations 13
3.5.3 Unit conventions 13
4 Overview of TSN in Industrial Automation 13
4.1 Control loop operation 13
4.2 Control Loop Applications 14
4.3 Network access 15
4.4 Mechanisms that can be used to meet Control Loop Latency Requirements 16
4.5 Integration of TSN in Industrial Automation 16
4.6 Industrial Traffic Types 17
4.6.1 General 17
4.6.2 Traffic type characteristics 18
4.6.3 Traffic type descriptions 19
5 Conformance 28
5.1 General 28
5.2 Requirements Terminology 28
5.3 Profile Conformance Statement (PCS) 28
5.4 Conformance Classes 28
5.5 Common requirements 29
5.5.1 Common PHY and MAC requirements 29
5.5.2 Common Network Discovery Requirements 29
5.5.3 Common Requirements for Synchronization 29
5.6 Common options 30
5.6.1 Common PHY and MAC options 30
5.6.2 Common Network Discovery Options 30
5.6.3 Common options for Synchronization 31
5.6.4 Common options for Security 31
5.7 Bridge requirements 31
5.7.1 Common Bridge requirements 31
5.7.2 ccA Bridge Requirements 32
5.7.3 ccB Bridge Requirements 32
5.8 Bridge Options 33
5.8.1 Common Bridge Options 33
5.8.2 ccA Bridge Options 34

AVA Documents
Document Sharing Hub
Full document details: 20/30423044 DC

5.8.3 ccB Bridge Options 34
5.9 End Station Requirements 34
5.9.1 Common End Station Requirements 34
5.9.2 ccA End Station Requirements 34
5.9.3 ccB End Station Requirements 35
5.10 End station Options 35
5.10.1 Common End Station Options 35
5.10.2 ccA End Station Options 35
5.10.3 ccB End Station Options 36
6 Required Functions for an Industrial Network 36
6.1 General 36
6.2 Synchronization 36
6.2.1 General 36
6.2.2 Grandmaster PTP Instance requirements 36
6.2.3 PTP End Instance requirements 36
6.2.4 Requirements for Application Clock 37
6.2.5 Requirements for Working Clock Domain 37
6.2.6 Requirements for Global Time Domain 37
6.2.7 IA-device model for clocks 37
6.2.8 Error Model 38
6.2.9 gPTP Domains 39
6.2.10 Cold Standby Redundancy for Time Synchronization 40
6.2.11 Hot Standby Redundancy for Time Synchronization 40
6.3 Security Model 40
6.4 Bridge delay requirements 40
6.5 Network access 40
6.6 Bridge FDB requirements 40
6.6.1 FDB configuration for TSN streams 40
6.6.2 FDB configuration for non-TSN streams 40
6.7 Bridge resource requirements 40
6.8 Management 41
6.8.1 General 41
6.8.2 Engineering management model 41
6.8.3 Operation 42
6.8.4 Managed Objects 44
6.8.5 Protocols 44
6.8.6 Engineering Management Quantities 45
Annex A (normative) PCS proforma – Time-sensitive networking profile for industrial automation 46
A.1 General 46
A.2 Abbreviations and special symbols 46
A.2.1 Status symbols 46
A.2.2 General abbreviations 46
A.3 Instructions for completing the PCS proforma 47
A.3.1 General structure of the PCS proforma 47
A.3.2 Additional information 47
A.3.3 Exception Information 47
A.3.4 Conditional status 48
A.3.5 Electronic Datasheet 48

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

A.4 Common requirements 48
A.4.1 Implementation identification 48
A.4.2 Profile summary, IEC/IEEE 60802 49
A.4.3 Implementation type 49
Annex B (informative) Representative TSN Domain 50
B.1 Case 1 50
Annex Z (informative) Gaps 51
Z.1 Hot standby redundancy for time synchronization 52
Z.1.1 General 52
Z.1.2 Overview 52
Z.1.3 PTP Instance configuration 53
Z.1.4 60802_Instance state machine 53
Z.1.5 State machine global variables 53
Z.1.6 60802_InstanceState: 54
Z.1.7 State machine local variables 54
Z.1.8 State machine functions 54
Z.1.9 State diagram 55
Z.1.10 60802_System state machine 56
Z.1.11 State machine global variables 56
Z.1.12 State machine local variables 56
Z.1.13 State requirements 57
Z.1.14 State diagram 57
Bibliography 59

Figure 1 –Data flow in a control loop 14
Figure 2 – Isochronous network Access 15
Figure 3 – Clock usage principles 38
Figure 4 – Error scheme – Local clock 39
Figure 5 – Industrial Automation Management Entity (IA-ME) 42
Figure 6 – Operational Management Model 43
Figure Z.1 – Model of hot standby redundancy for time sync 53
Figure Z.2 – 60802_Instance state diagram 55
Figure Z.3 – 60802_System state diagram 58

Table 1 – List of terms 10
Table 2 – Application Requirements 15
Table 3 – Industrial automation traffic types summary 17
Table 4 – Application-centric communication characteristics 18
Table 5 – Characteristics of isochronous traffic type 19
Table 6 – Characteristics of cyclic-synchronous traffic type 21
Table 7 – Characteristics of cyclic-asynchronous traffic type 22
Table 8 – Characteristics of alarms and events traffic type 23
Table 9 – Characteristics of configuration and diagnostics traffic type 24
Table 10 – Characteristics of network control traffic type 25
Table 11 – Characteristics of best effort traffic type 26
Table 12 – Characteristics of video traffic type 27

AVA Documents
Document Sharing Hub
Full document details: 20/30423044 DC

Table 13 – Characteristics of audio/voice traffic type 28
Table 14 – gPTP Domains 39
Table A.1 – Implementation identification template 49
Table A.2 – Profile summary template 49
Table A.3 – Implementation type template 49

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

Time-Sensitive Networking Profile for Industrial Automation

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation.

   IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. IEEE documents are made available for use subject to important notices and legal disclaimers (see http://standards.ieee.org/IPR/disclaimers.html for more information).

   IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.

3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC/IEEE Publication or any other IEC or IEEE Publications.

8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Documents
Document Sharing Hub

Full document details: 20/30423044 DC

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 society[1], 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.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

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

Assistance to experts drafting IEC documents:

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.

Documents
Document Sharing Hub

Full document details: 20/30423044 DC

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.

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

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

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

Term	Source
Relative time error (TER)	ITU-T G.8260
station	IEEE Std 802®-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

3.3 TSN-IA defined Terms

3.3.1
application clock
clock used by the application to time events in the application

3.3.2
Application Data Cycle
user-defined time interval required for data-exchange between applications

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

3.3.3
Deadline
application-defined fixed time reference point within the network cycle

3.3.4
external error
error introduced in the system by for example receiving time from GPS to synchronize the Clock of the Global Time Grandmaster PTP Instance

3.3.5
Global Time
synchronized time in a network that is traceable to a known source

3.3.6
IA-controller
entity that exchanges data with several IA-devices for the purpose of control of a system

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

3.3.7
IA-device
entity that exchanges data with an IA-controller for the purpose of control of a system

3.3.8
Isochronous Application
application that is synchronized to the Working Clock that is synchronizing network access

3.3.9
Network Access
action of placing frames on the network or of collecting frames from the network

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

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

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.

AVA Documents Document Sharing Hub

Full document details: 20/30423044 DC

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.

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

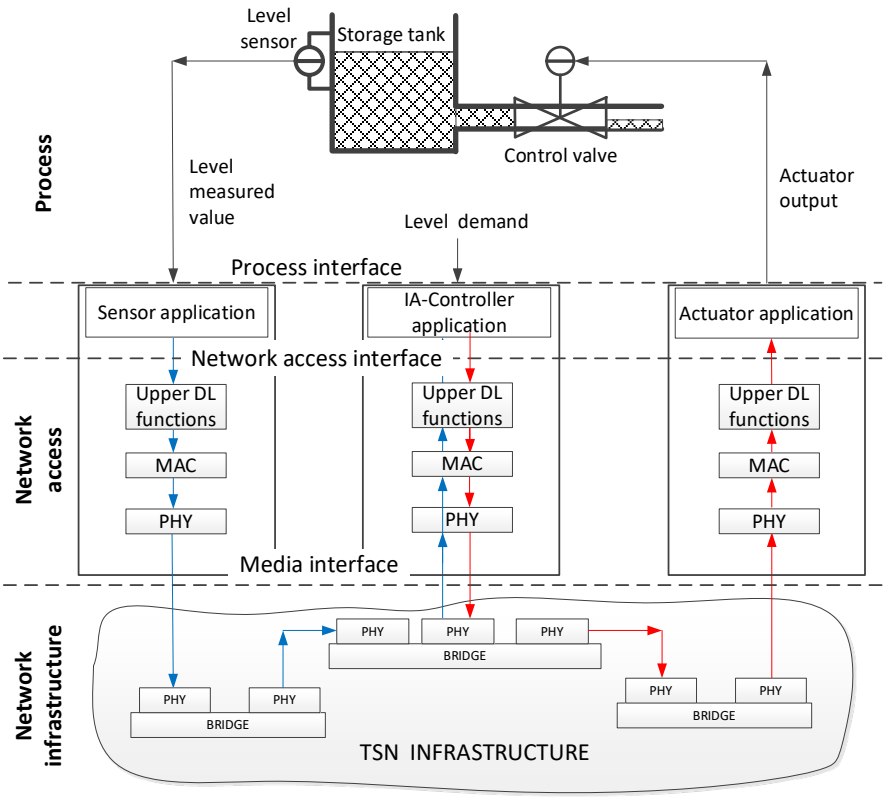

Figure 1 –Data flow in a control loop

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

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

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 µs. 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

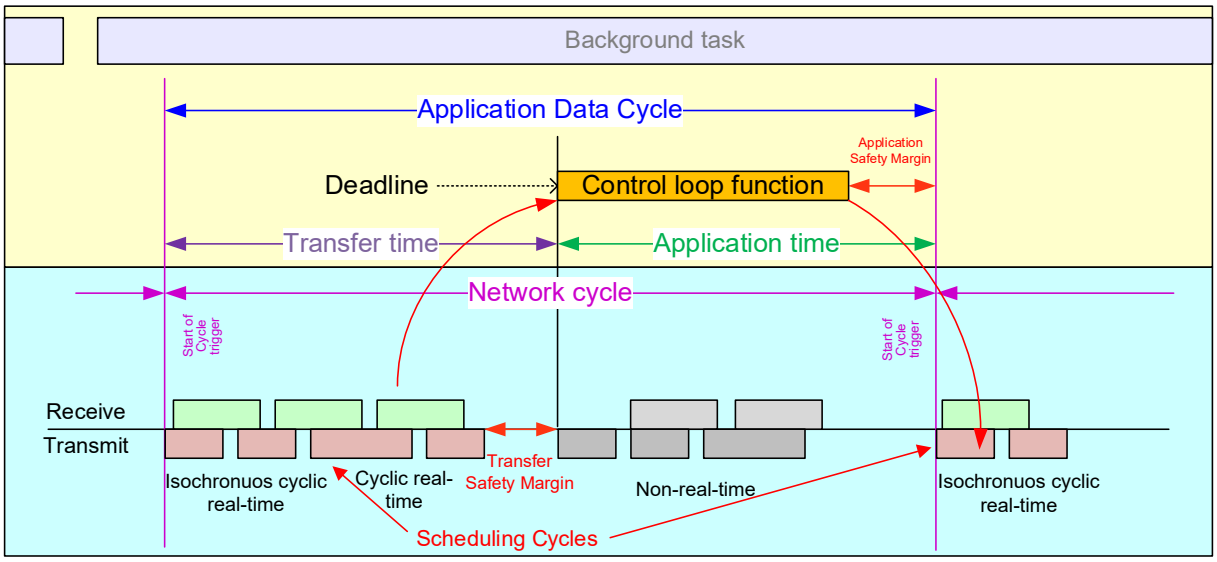

Figure 2 – Isochronous network Access

Documents
Document Sharing Hub
Full document details: 20/30423044 DC

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

Documents
Document Sharing Hub

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

AVA Documents
Document Sharing Hub
Full document details: 20/30423044 DC